COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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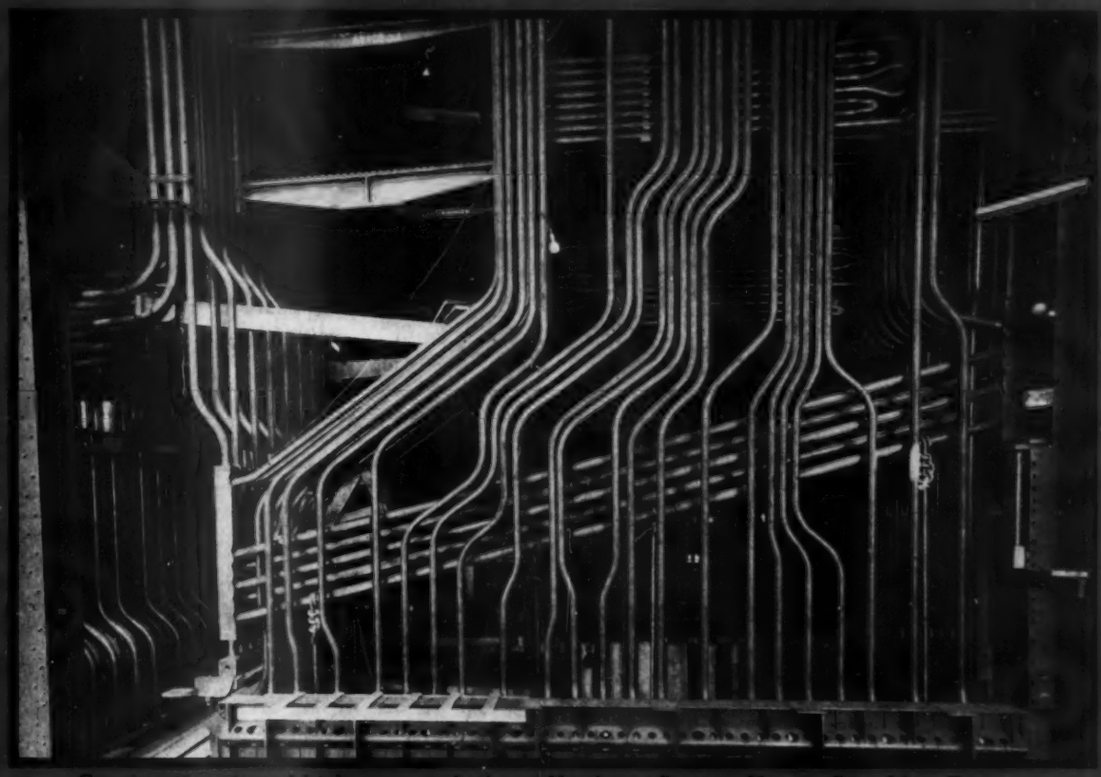

Construction view of high-pressure boiler at Northeast Station, Kansas City, Mo. Furnace walls and superheater in place with space at upper left for insertion of the economizer

Evaporators and Their Applications

Circulation in Boiler Tubes

Fuels of Today and Tomorrow

C-E Steam Generators, Type VU

have been bought for THIS RANGE

of capacities, pressures, temperatures, and fuels

A PARTIAL LIST OF CONTRACTS

CAPACITY PER UNIT (lb per hr)	DESIGN PRESSURE (lb per sq in.)	TOTAL TEMP. (deg F)	NO. OF UNITS	COMPANY	PLANT LOCATION	FUEL
20,000	350	700	1	Taggart Bros. Co., Inc.	Herring, N. Y.	P.F.
30,000	450	725	1	National Container Corp.	Jacksonville, Fla.	Wood Bark & Oil
35,000	450	730	2	Fulton Bag & Cotton Mills, Inc.	Atlanta, Ga.	P.F.
40,000	425	675	2	Allied Paper Mills	Kalamazoo, Mich.	P.F.
45,000	300	366*	1	Cannon Mills Co.	Concord, N. C.	P.F.
50,000	200	465	1	Dunlop Tire & Rubber Co.	Toronto, Ont., Canada	P.F.
55,000	650	650	2	The Celluloid Corp.	Newark, N. J.	P.F. & Oil
60,000	500	665	2	Armour & Co.	East St. Louis, Ill.	P.F.
70,000	300	470	1	Acadia Sugar Refining Co., Ltd.	Dartmouth, Nova Scotia	P.F. & Oil
75,000	225	440	1	University of Tennessee	Knoxville, Tenn.	P.F.
80,000	400	650	1	Granby Consolidated Mining, Smelting & Power Co.	Princeton, B. C.	P.F.
90,000	500	750	1	Filer Fiber Co.	Filer City, Mich.	P.F.
100,000	450	700	3	Great Lakes Steel Corp.	Detroit, Mich.	Oil & B.F. Gas
110,000	475	750	4	Sanitary District of Chicago	Chicago, Ill.	P.F. & Sewage Sludge
120,000	450	715	1	The Brown Company	Berlin, N. H.	P.F.
160,000	725	835	2	Kansas Gas & Electric Co.	Wichita, Kans.	Oil & Gas
200,000	525	760	2	Nebraska Power Co.	Omaha, Nebr.	Oil & Gas

*Saturated steam temperature at present operating pressure.

THE above partial list of contracts evidences the wide variety of fuel and operating conditions to which the Type VU Steam Generator is applicable.

Type VU Steam Generators are completely standardized units, identical in design features regardless of size. A 20,000-lb capacity unit is similar in all respects to a 200,000-lb unit, the drum sizes, amount of heating surface and general dimensions being varied in standard increments to suit particular requirements.

Emphasis may properly be placed on the many special design features and the uniformly high quality of construction which distinguish the Type VU Generator. These characteristics assure exceptional economic and operating reeults and are responsible for the widespread popularity of this modern unit, as evidenced by its purchase for plants in every section of the country and in virtually all major industries.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINE NUMBER TWO

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Hirschfelde Power Station

A 2-drum, bent-tube boiler set over a completely water-cooled furnace burning pulverized lignite. A load drop from 220,000 to 110,000 pounds per hour within a 5-minute period changed the boiler water level only 4.5 inches. Write for—German Experiences with Load and Level Feed Regulation—a paper by D. W. Rudorff originally published in POWER.

Maurits Power Station

A 485-pound pressure longitudinal drum boiler with capacity of 242,000 pounds per hour. Loads sometimes drop as much as 10,000 kw. almost instantaneously. Better boiler operation is obtained when a higher water level is carried on heavy loads than on light. Charts showing "before and after" results were reproduced with Dr. Ir. F. W. van Berckel's article—Handling "Swell" in High Pressure Boilers—published in POWER PLANT ENGINEERING.

Pennsylvania Sugar Co.

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Portland Gas & Coke Co.

Three 600-horsepower boilers using waste heat from single-shell oil-gas generators. Steam output of each boiler increases from zero to more than 200 percent of rating in seven minutes, then drops again to zero in five minutes. This operating cycle is continuous. Despite these severe conditions, the total boiler water level variation is only 5.75 inches. Write for B. G. Dick's paper—Feed Water Regulation for Violently Fluctuating Loads—originally published in POWER.

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COPES

SYSTEM OF BOILER FEED CONTROL

BRANCH PLANTS IN CANADA - ENGLAND - FRANCE - GERMANY - AUSTRIA - ITALY - SALES AND SERVICE REPRESENTATIVES IN PRINCIPAL INDUSTRIAL CENTERS THROUGHOUT THE WORLD

EDITORIAL

Pressing Forward

THE voluminous report on "Technological Trends and National Policy," just issued by the National Resources Committee, contains an excellent chapter on "Power" by Dean A. A. Potter of Purdue University and M. M. Samuels of the Federal Power Commission, in which there is the following reference to research necessary to reduce power costs:

"New knowledge is needed to construct steam generators which are efficient and safe at much higher temperatures and pressures than those now in use and which will at the same time be inexpensive, have high rates of output, low maintenance, a high degree of availability and adaptability to different fuels and waters."

As a milestone in power plant progress, the accomplishments of the past two years are comparable to those of the period closely following the War, but the indications, as cited in the above quotation, are that, without waiting to assess the experiences based on recent practice, further advances of large magnitude will be undertaken.

Notwithstanding the large number of superimposed installations that have already been made, are under construction or are now under consideration, it is probable that only a part of the remaining two hundred to two hundred and fifty pound stations will be found susceptible to economical topping. After these have been extended, will the next general move be in the direction of building new plants or topping the existing four hundred to six hundred pound stations? Present indications are that both may be expected.

Already work has been started on a number of new stations and others are in the planning stage, at least four of which will employ fourteen hundred pounds pressure and the straight condensing cycle, and several others will operate at eight hundred to nine hundred pounds pressure and at around nine hundred Fahrenheit total steam temperature. More in this latter group are likely to be laid down in the near future. Also, semi-outdoor construction is now here in the case of one plant that went into operation last year and two more upon which construction is about to begin. As for topping the four hundred to six hundred pound stations, one such installation is now under way and intensive studies are being made in connection with some others.

There seem to be two schools of opinion concerning the wisdom of topping four hundred to six hundred pound stations inasmuch as initial pressures of around twenty-five hundred pounds are required for the latter to afford the desired additional power. On the one hand, it is contended that the majority of existing stations in this class are only twelve to fourteen years old, some less; that the boilers in most cases are still in excellent condition and operating at good efficiency; that station heat rates of fourteen thousand to sixteen thousand Btu per kilowatt-hour are being obtained; that the feed pump power for a twenty-five hundred pound boiler is likely to be excessive; and that despite an initial steam temperature of over nine hundred degrees, reheat will be necessary. To top such plants would mean scrapping some of the present boilers, whose useful life is only partly written off, and the assumption of new operating problems in return for a gain of two or three thousand Btu in the station heat rate, which is small compared with the gain through topping a lower pressure station with fourteen hundred pounds.

On the other hand, it is pointed out that by adopting such high pressures additional capacity in many cases can be obtained at less initial cost, despite the necessity for forged drums and extra heavy boiler appurtenances, than that involved in a new plant, in addition to which there is the improvement in station heat rate of the existing stations. Attention is also called to the fact that similar arguments were advanced some years ago when pressures were increased from four hundred to fourteen hundred pounds. However, such installations have proved reliable, efficient and easy to operate.

The advent of twenty-five hundred pounds pressure involves still further subordination of boiler heating surface to water wall and economizer surface which will tend to keep down the initial cost of the steam generating unit although the total cost will still exceed that of a fourteen hundred pound installation when all the various accessories are considered.

Reverting to the quotation from Dean Potter and Mr. Samuels, there are likely to be fewer problems connected with the employment of higher pressures than in the use of higher steam temperatures. While only a few of the recent installations employing steam temperatures of nine hundred to nine hundred and twenty-five Fahrenheit are in service, these appear to be operating with complete satisfaction. Others are being laid down for temperatures up to nine hundred and sixty degrees. Nevertheless, further research together with the accumulated experience of many such installations in commercial operation over a considerable period would seem desirable before increasing the steam temperatures still further by any considerable amount.

New Steam Generating Unit Carries Morris Paper Mills Load

By J. A. REITZEL,
Supt., Morris Paper Mills

A bent-tube boiler, fired with a traveling grate stoker burning local Illinois coal, carries the entire paper mill load formerly handled by several smaller units and has effected a 25 per cent saving in fuel. The unit has been in continuous operation since going into service over six months ago and has shown an availability factor of 97.6 per cent. Test results are given.

THE present high availability of modern steam generating units, which has been largely responsible for the trend in the public utility field toward the employment of a single boiler per turbine, in some cases supplying the entire station load, has also influenced industrial power plant practice throughout the country. The recent installation at the plant of the Morris Paper Mills at Morris, Illinois, is an excellent example of this trend. Here, instead of operating three or four small size boilers as formerly, the entire load of the mills is now being carried on one boiler.

This boiler, which has been in continuous operation since the first of the year, is of the C-E four-drum bent-tube type, containing 10,170 sq ft of heating surface and rated at 80,000 lb of steam per hour. Although designed for a future operating pressure of 450 lb, steam is at present being generated at 210 lb pressure and 120 deg superheat with feedwater entering the economizer at

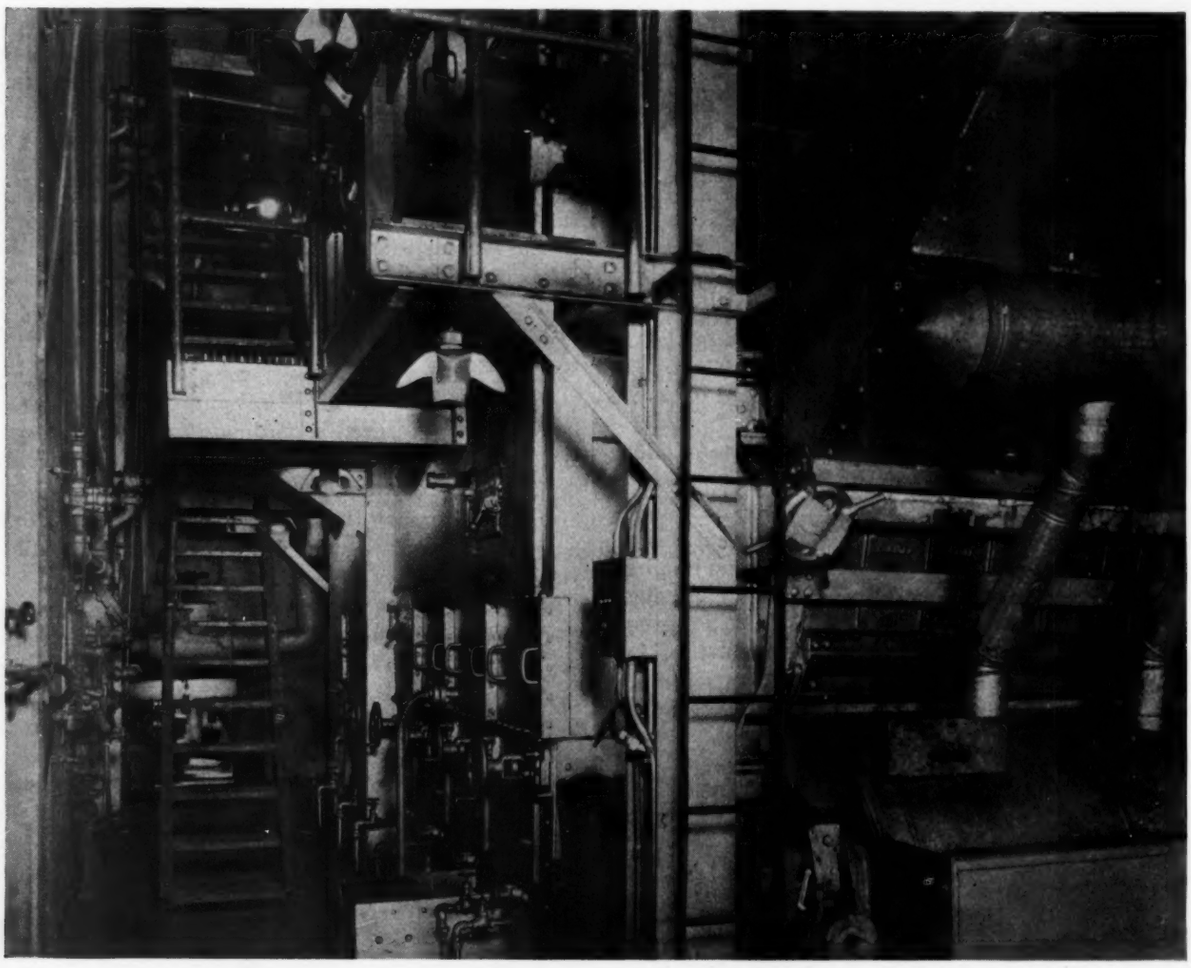

Fig. 1—Side view of boiler showing stoker air control

216 F. The Elesco superheater is so designed that final steam temperature may be increased at some later date, when the pressure is increased, by adding more superheating surface.

The steam demand varies from 60,000 to 80,000 lb per hr with a 24-hr load, five or six days a week, the hourly rates, of course, depending upon the variations in process and heating demands.

Morris is located in the northern Illinois coal fields where both strip mine coal and some third vein coal are available. The economy obtainable by using this local coal had a very definite bearing on the type of fuel burning equipment selected. The proximate analysis of this coal is as follows:

Fixed carbon, per cent	42.13
Volatile, per cent	28.96
Ash, per cent	18.01
Moisture, per cent	10.90
Sulphur, as received, per cent	4.02
Btu per lb as fired	10,030

A Coxe traveling grate stoker was selected as best fitted to burn this coal, particularly because continuity

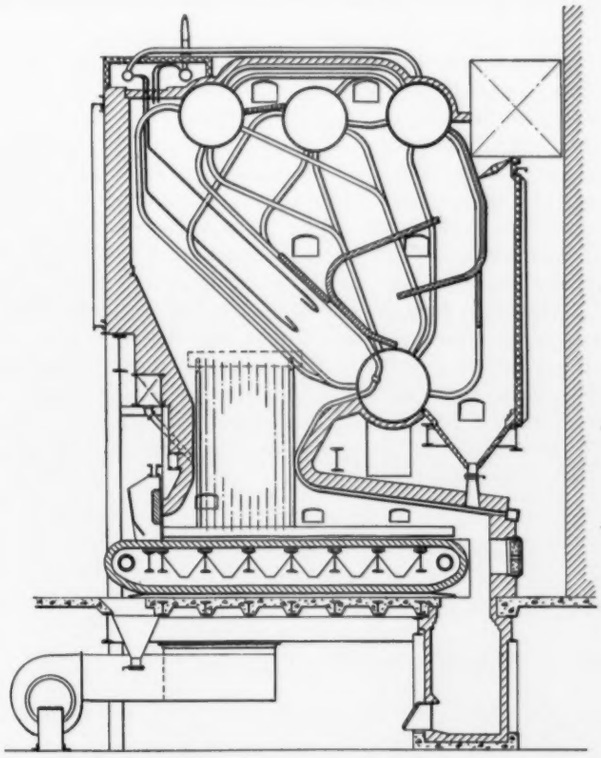

Fig. 2—Cross-section through boiler

of operation and the highest degree of availability were primary considerations. In this design of stoker there is little likelihood of serious outage through failure of the operating mechanism and the grate elements can be replaced, if necessary, without shutting down the unit—a feature not possible with any other type of grate surface. The non-sifting feature of the grate was also important.

The stoker is 17 ft wide, $16\frac{1}{2}$ ft long and has an effective grate area of 255 sq ft, thus making the ratio of grate surface to boiler heating surface approximately 1 to 40. A full water-cooled rear arch is employed to assist in thorough mixing of the gases and to avoid stratification. The side walls of the furnace are water cooled and overfire air is employed.

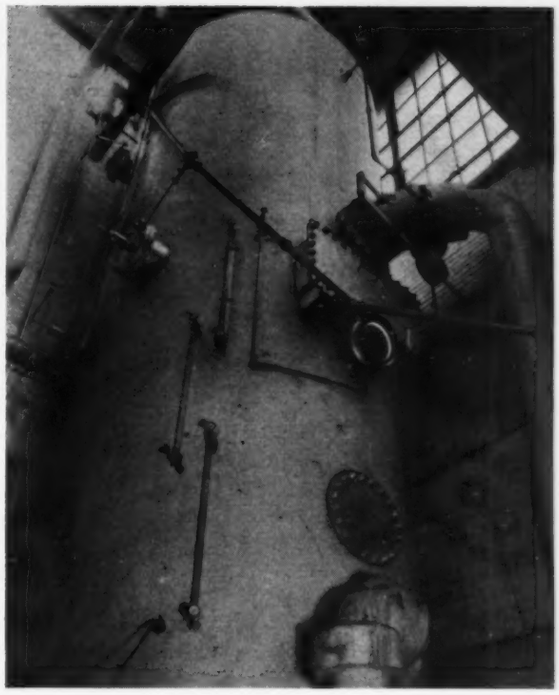

Fig. 3—Combination water softener and deaerating heater

Forced- and induced-draft fans of the Clarage type are installed, a Copes feedwater regulator is provided and the unit is equipped with a complete automatic combustion control of the Hagan type.

The availability of the complete unit from the time it took over the full plant load on December 20 up to July

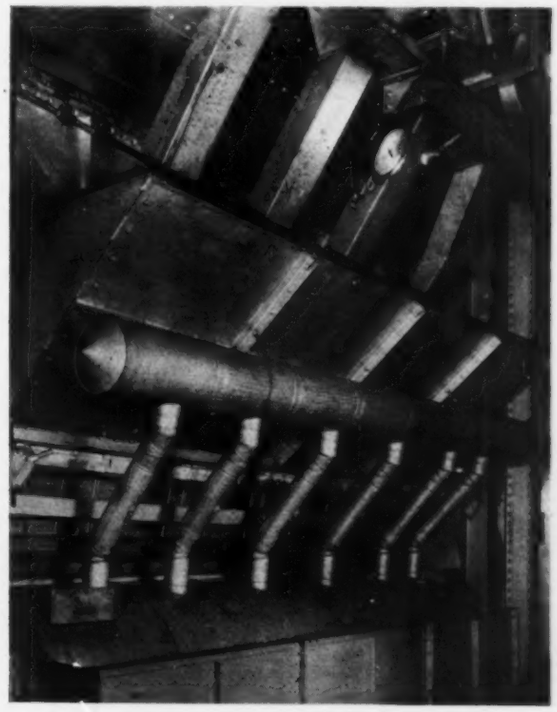

Fig. 4—View of stoker front and hoppers

The stoker front is enclosed and its front cooled by sucking boiler room air through slots at the bottom of the panels and drawing this up through the cylindrical manifold which discharges to the overfire air duct. This also serves to keep the operating floor both cool and clean.

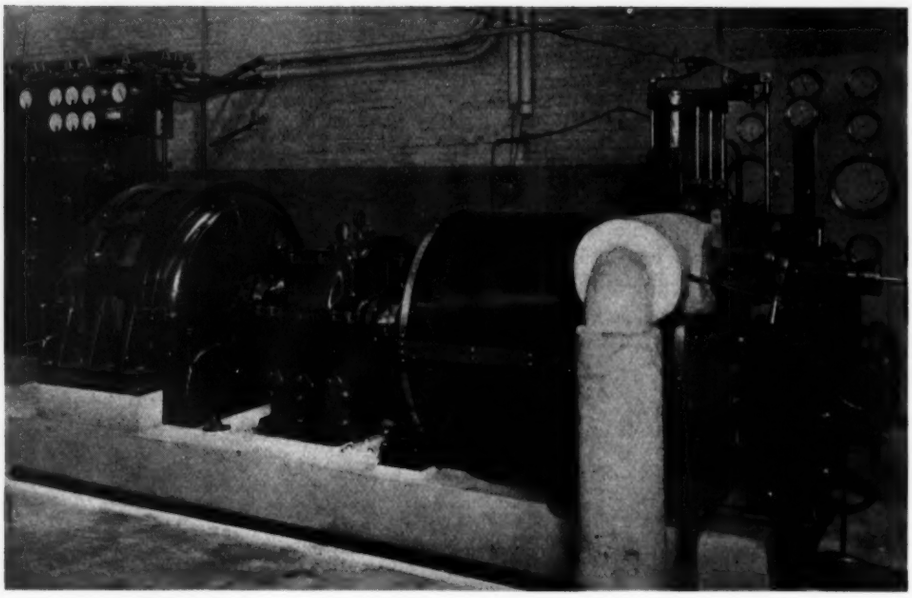

Fig. 5—A new 500-kw turbine has also been installed driving a generator which supplies mill service

15, the time of the present writing, has been 97.6 per cent.

The overall efficiency of boiler, stoker and furnace during a 48-hr test, while the average steam generated per hour was 70,600 lb, was 76.88 per cent. This does not include the heat recovered by the economizer. The gases from this boiler discharge through a Green fuel economizer, which was formerly used with the old boilers. Taking into consideration the heat recovered by the economizer during this same 48-hr period, the overall efficiency figures 80.34 per cent. A heat balance for boiler, stoker and furnace is given below:

	Per Cent
Loss due to moisture in coal	2.26
Loss due to water from combustion of hydrogen	4.81
Loss due to dry chimney gases	12.02
Loss due to gaseous combustibles	0.00
Loss due to unburned carbon in refuse	2.03
Loss due to radiation	1.00
Loss due to solid carbon in gases (assumed)	1.00
Total losses	23.12
Efficiency, by difference (100–23.12)	76.88

During this test the men regularly employed at the plant operated the unit in the customary way. The automatic control system handled the normal load fluctuations very satisfactorily. The only attention required by the operator was to make slight changes in the fuel-air ratio relay as major load changes occurred.

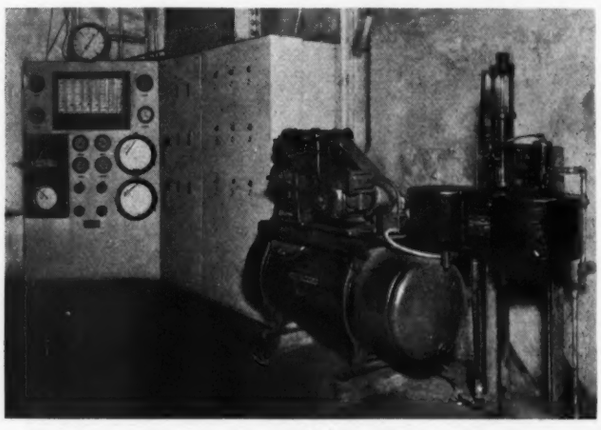

Fig. 6—Automatic combustion control system including control panel and compressor

Whereas the five boilers initially housed in this boiler room provided only 50 per cent standby capacity, today with four boilers in the boiler room, including the new unit described, there is practically 100 per cent standby capacity. The difference in economy of the plant, based on six months of operation, compared to former operation represents a saving of approximately 25 per cent of the annual fuel bill. Further economies have been made in reduced maintenance and in other operating costs.

Coincident with the installation of the new boiler unit, a Cochrane hot-process softener was installed and two high-pressure centrifugal feed pumps. Shortly after the new boiler and water softener were put into operation, a new 500-kw Elliott turbine-generator was installed as a house turbine. The accompanying photographs show these installations.

Sees Menace to Coal Industry

"The disastrous consequences to the coal industry of any large-scale hydroelectric program are self-evident, although as yet but faintly realized," says R. E. Howe, vice president of Appalachian Coals, Inc., who adds:

"We face the indisputable fact that thousands of miners and railroad workers will be made jobless whenever big coal tonnages are displaced. Also, scores of communities, dependent solely on the coal mining industry, would suffer. Another important point, too often overlooked, is that in the territory embracing eastern Kentucky, eastern Tennessee, southwestern Virginia and southern West Virginia, the coal operators spend annually over 105 million dollars of which 68 million goes for wages, 34 million for mine and commissary supplies and 3 million for Federal, State and County taxes. Industries which receive a large share of the miners' dollars and other lines of business dependent upon the coal industry for equipment orders are also threatened when hydro power threatens bituminous coal."

EVAPORATORS and Their Applications

By ROBERT D. SPEAR

Foster Wheeler Corporation

Following a review of the conditions leading up to the extensive use of evaporators in modern high-pressure plants, the author gives and discusses flow diagrams of typical arrangements as employed in large plants of different industries.

EVAPORATORS have contributed to the development of the modern high-pressure steam boiler by furnishing a safe, dependable supply of distilled water makeup. Boiler installations have grown so impressively in pressure and size as to obscure the fact that evaporator designers have consistently met the demand for feedwater of steadily increasing purity as required by the boiler designer and operator.

Many years ago the advent of boilers in seagoing vessels necessitated the use of an evaporator, or "distiller" as it is still called, to distill fresh water from sea water as makeup. The apparatus was necessarily light and compact, using steam at boiler pressure through a reducing valve. As the steam coils became caked with salt scale day by day, the pressure was increased. At the end of each run the coils were removed and descaled by hammering and chipping. Economy was sacrificed for space and weight. Since boiler pressures were usually not more than 150 to 200 lb gage, crude separators served to remove enough moisture from the evaporated vapor to provide makeup of satisfactory quality.

Power plant engineers, designing "high-pressure" central stations for 300 and even 400 lb gage pressure, in the early years of the last decade, learned that the marine evaporator was readily adaptable to their use and could be made to fit economically into the station heat balance. Some engineers used auxiliary exhaust steam to supply heat to the evaporator unit, with low-temperature condensate from the condenser hotwell as the condensing

Fig. 1—Two of three large single-effect evaporators in an automobile plant

medium. Others followed marine practice more closely with live steam supplied to the evaporator through a reducing valve, with boiler feed on the discharge side of the feed pump as the condensing medium. Makeup requirements averaged from 4 to 5 per cent and most evaporator units were, of necessity, arranged for double-effect operation to fit the station heat balance.

With the adoption of the regenerative cycle and motor-driven auxiliaries, steam for the evaporators became available at several bleed pressures while makeup requirements were reduced to between 1 and 2 per cent. This condition was suited to smaller, single-effect evaporators installed between turbine bleed points. General practice today follows this arrangement, for although boiler pressures have greatly increased, suitable bleed points remain for the evaporator installation at pressures much the same as before.

The required standards of purity for distilled boiler feed makeup have been steadily raised due to the much closer control of boiler water conditioning occasioned by higher steam pressures and temperatures. Separators for evaporators have been developed which reduce the solid content of the evaporated vapor to not more than 0.20 to 0.25 grains per gallon, thus providing makeup suitable for boilers operating at the highest pressures.

Other important developments in evaporator design are: (1) general use of welded steel plate shells of A. S. M. E. Code construction; (2) arsenical copper steam coils, highly resistant to corrosion and fatigue; and (3) Lockhead construction for removable shell covers of large-diameter, high-pressure evaporators.

Many industrial plants have utilized the economy of high steam pressure in the generation of "by-product" power in supplying their process steam demands. The primary requirement of such an installation is, complete reliability coupled with a satisfactory return on investment. The "heat-transformer" evaporator has met these conditions fully, as evidenced by the many installations in operation here and abroad. The most economical arrangement for a particular plant will depend upon the requirements of that industry and, more specifically, on heat and power requirements of the plant itself. Such widely divergent industries as automobile, rubber, chemical, rayon, heavy machinery, paper, steel, oil refining and building material manufacture have profited from the heat-transformer arrangement.

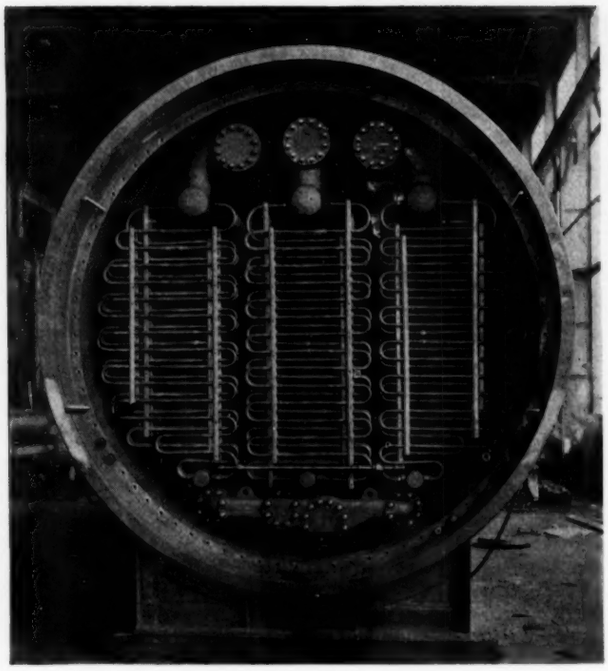

Fig. 2—One of the evaporators of Fig. 1 with shell cover and diaphragm plate removed

Referring to a typical heat-transformer installation serving a 300,000-lb per hr boiler and high-back-pressure turbine, W. K. Adkins, power engineer of the Firestone Tire and Rubber Company, says[1]

"We believe that this system assures maximum protection and reliability for this type of equipment. A water-softening system could have been purchased for a lower capital investment, but evaporators had these advantages:

"1. Water for a 1400-lb boiler has never been chemically softened. In this case if the turbine exhaust were led directly to the process steam lines, makeup requirements would have been approximately 80 per cent.

[1] "Firestone Goes to 1400 Lb at Akron," *Power*, February 1935, page 61.

Fig. 3—Central station makeup evaporators; that on left with coil bundle removed

"2. The total solids in our raw water supply are rather high, reaching a peak during the past year of 30 grains per U. S. gallon, 20 grains of it being sodium chloride, and necessitating excessive blowdowns even if the water could have been treated successfully.

"3. Evaporators minimized the possibility of solid carry-over from boiler to turbine, with resultant troubles and outages.

"4. They avoid probability of boiler failure, high maintenance, and the ever-present necessity (with the softener system) of accurate and infallible human control—all for the possibility of a slightly greater return on the investment."

regarded as cheap insurance against such a possibility. Furthermore, since all of the condensate is returned to the boiler, insuring freedom from impurities, the turbine is protected against blade deposits that would reduce its capacity and require frequent shutdowns for cleaning.

A study of the fixed and operating charges showed that for a factory steam supply pressure of 180 lb gage a turbine back pressure of 240 lb gage would give the lowest total cost. The heat head, or difference between the saturated steam temperatures at these two pressures, is 23.1 deg F. Reliability of operation far outweighed the additional saving that might be theoretically calculated by eliminating the evaporators and showing a

Fig. 4—(Below) Flow diagram of heat-transformer evaporator in large high-pressure automobile plant; see Fig. 1

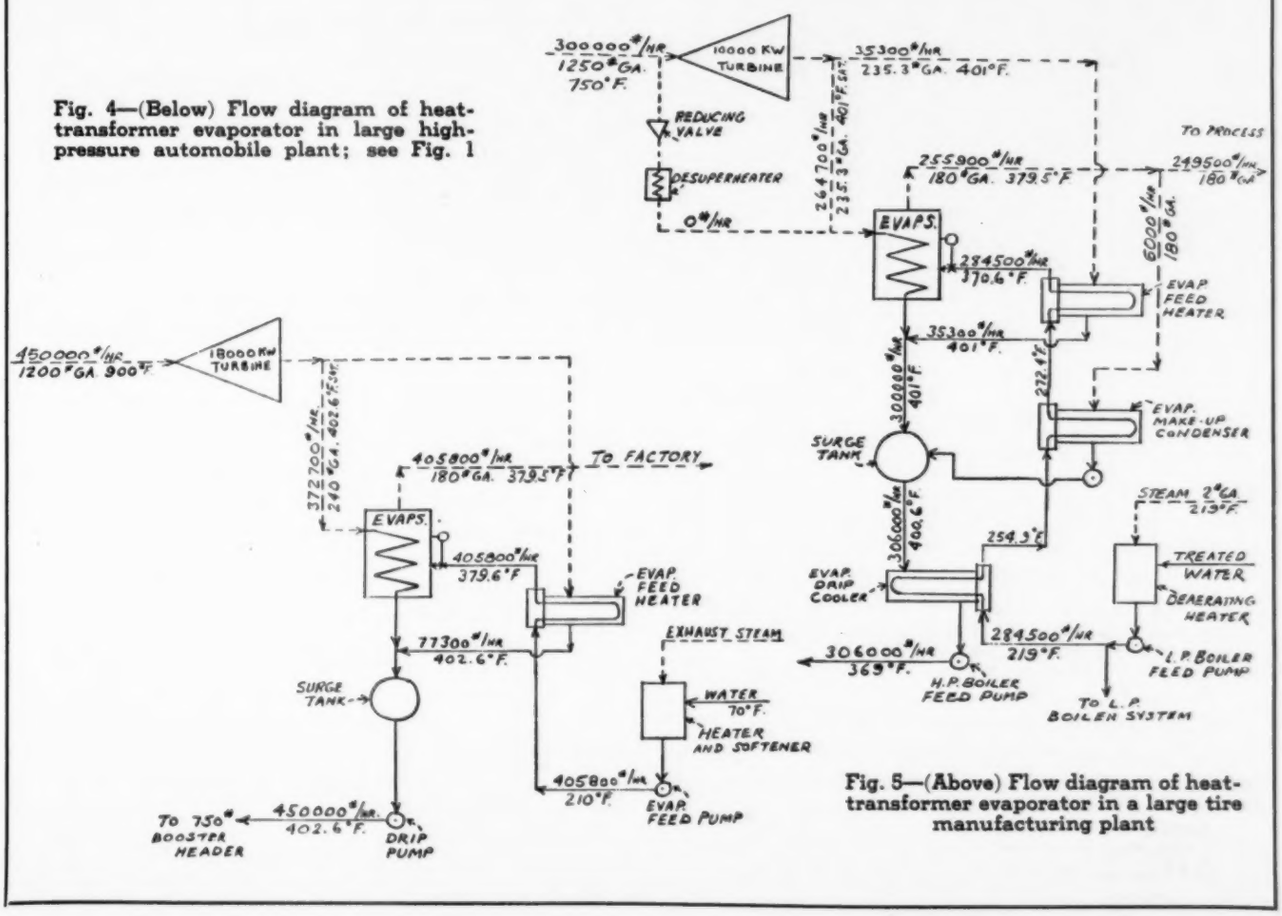

Fig. 5—(Above) Flow diagram of heat-transformer evaporator in a large tire manufacturing plant

The flow diagrams accompanying the present article illustrate some of the ways in which power engineers in various industries have provided by-product power and process steam for their plants, incorporating heat-transformer evaporators for reliable and economical operation.

Fig. 4 is a flow diagram of the heat-transformer evaporator unit in a large automobile plant. Increased factory requirements for low-pressure steam, most of which could not be returned to the boilers as condensate, made it feasible and economical to generate 18,000 kw in a 1400-lb pressure turbine, condensing the steam in the evaporators and returning it to the boiler system. A forced shutdown of the boiler would cause a costly interruption to production, so that the evaporators are

greater power output with a back pressure of 180 lb gage on the turbine.

Fig. 1 shows two of the three single-effect evaporators in this plant, which are operated in parallel. When one is out of service for descaling or inspection, full output is maintained with the other two, by increasing the turbine back pressure for that period. Each evaporator shell is 10 ft in diameter and 37 ft long, built for 225 lb gage working pressure.

Fig. 2 shows one end of the evaporator with the shell cover and Lockhead diaphragm plate and shear pieces removed. This design of head eliminates the use of large bolts and provides a permanently tight joint, quickly removed and re-assembled. The coil bundles are in three groups, manifolded to one steam and one

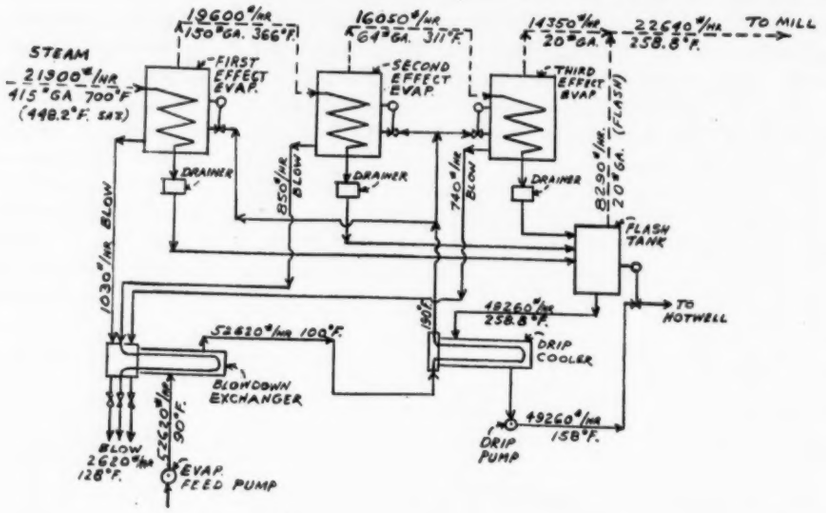

Fig. 6—(Right) Flow diagram of triple-effect evaporator in a rayon plant

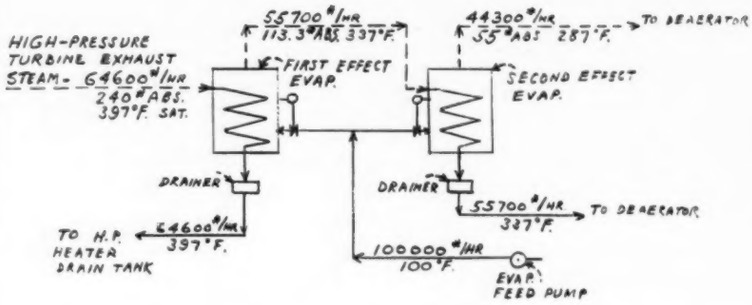

Fig. 7—(Left) Flow diagram of double-effect evaporator in industrial plant requiring high makeup

Fig. 8—(Right) Transformer evaporator in industrial plant having engines

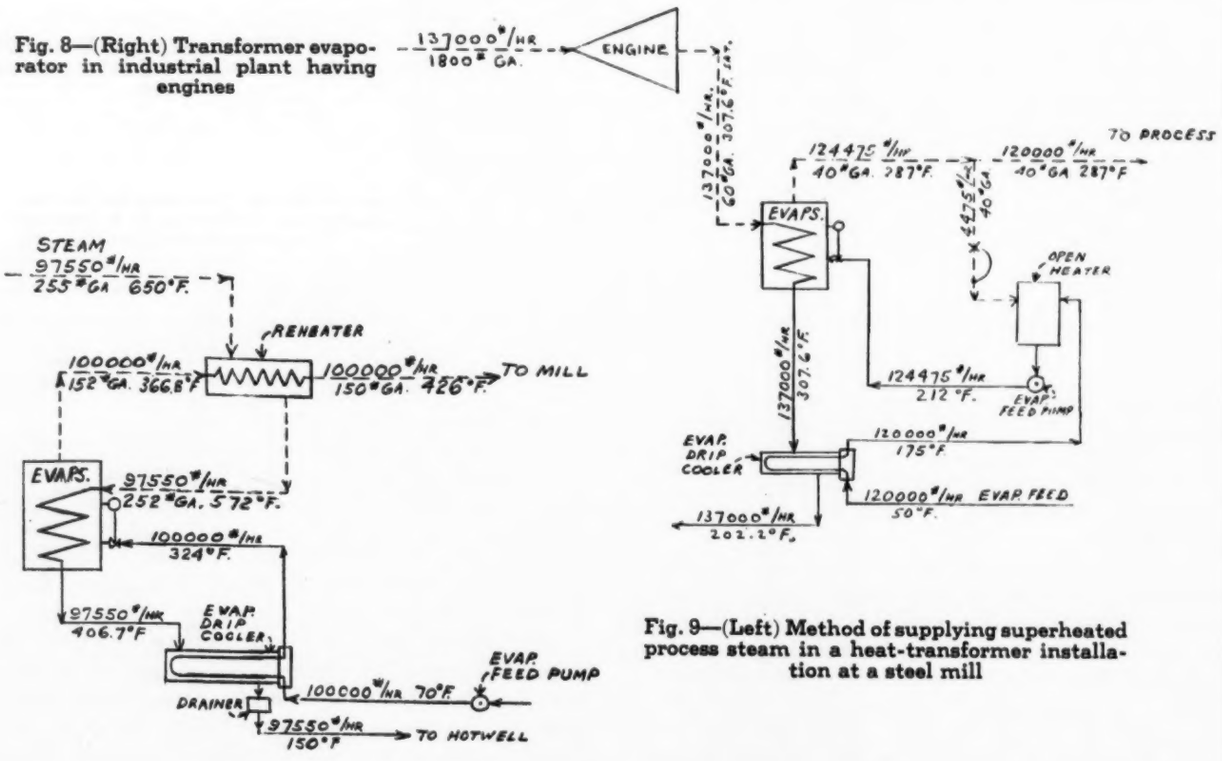

Fig. 9—(Left) Method of supplying superheated process steam in a heat-transformer installation at a steel mill

drain connection. A single, final vapor separator is provided in the vapor line, common to all three evaporators. Preliminary separation of moisture is accomplished by baffling in the upper portion of the evaporator shells.

Fig. 5 is a flow diagram of another large heat-transformer evaporator unit, in a tire factory. The arrangement is similar to Fig. 4, except that the coil drips are cooled and a small makeup condenser is added. Five evaporator shells in parallel comprise this installation. The heat head is 21.5 deg F.

In some plants, where steam demands vary considerably, a multiple-effect evaporator is installed. Such a case is shown in Fig. 6, which is the flow diagram for a triple-effect evaporator unit supplying the large percentage of boiler feed makeup required by a rayon plant and at the same time furnishing considerable process steam. If more process steam is required, double-effect operation is used. Production of makeup is regulated to meet the plant demand by throttling the steam pressure to the first effect. This is done automatically through a control valve actuated by the water level in the condensate storage tank. The heat in the steam supplied by the evaporator is completely "transformed" into process steam and makeup.

Another example of fitting an evaporator unit into the heat balance of a large industrial power plant is shown in Fig. 7. The percentage of makeup is high, requiring double-effect operation. Heat is absorbed in the plant deaerating heater, heating condensate returns and in the high-pressure feedwater heater. Output is regulated by throttling the steam pressure, automatically controlled by the level in the condensate return tank.

Fig. 8 represents the heat-flow diagram of a heat-transformer evaporator supplying process steam in a large industrial plant. The evaporator unit consists of three shells in parallel. The heat head is 20.6 deg F.

The method of supplying superheated process steam in a heat-transformer installation at a large steel mill is illustrated in Fig. 9. Steam supplied to the evaporator passes first through the shell of a steam-to-steam reheater, giving up enough heat to add approximately 60 deg superheat to the steam generated by the evaporators, which passes through the reheater tubes. The reheater is designed for a low-pressure drop on both the high- and low-pressure sides, so that the maximum effective pressure difference is maintained across the evaporators.

It has been generally found economical to use a heat head of approximately 22 deg F in single-effect heat transformer installations. Heat transfer rates fall off rapidly below 20 deg F which tends to make this the lower limit. The exact figure will depend chiefly on the cost of by-product power. In many cases, two or three different steam pressures will be in use in the plant, fixed by process requirements. Single-, double- or triple-effect evaporators may be used to fit these pressures, with a maximum of 100 deg F heat head per effect to avoid excessive ebullition, taking steam at one pressure into the coils, and generating steam in the evaporator shell at some lower pressure.

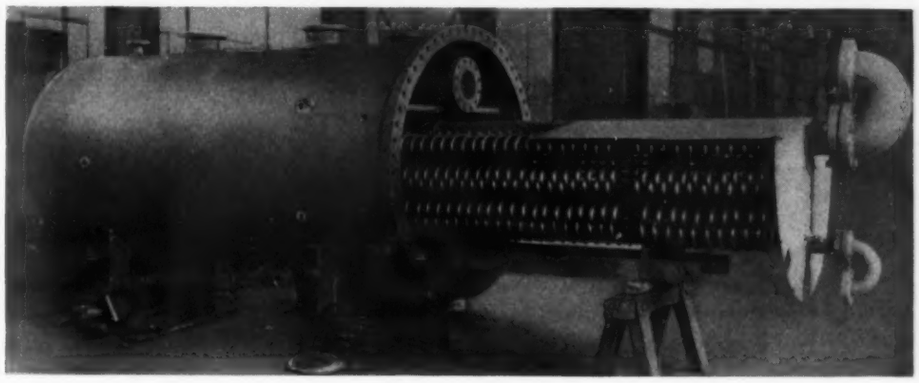

Fig. 10—Later type of evaporator with vapor baffling

Evaporators Applicable to Use in Central Heating Plants

Central heating plants are also well suited to the application of heat-transformer evaporators in connection with high-pressure boilers and back-pressure turbines. One plant now under construction will use this system to generate 100,000 lb per hr of steam at 70 lb gage pressure for use in the heating mains and low-pressure turbines. The evaporators take the high-pressure, 4000-kw turbine exhaust at 225 lb gage. The heat head is 22.1 deg F. Two evaporators, each 10 ft in diameter and 32 ft in length, are used. Treated evaporator feed is heated from 212 F to 375.2 F in a closed preheater, with steam at 170 lb gage.

Many large heat transformer installations are supplied with chemically softened evaporator feed. Pretreatment is not necessary, but is usually found to be economical for large units, as higher heat transfer rates are obtained, requiring less evaporator surface, and heat losses incidental to the descaling process are eliminated. Complete softening is not required, and the effects of over-or-under-treatment are not apt to be serious. In any case, only the process steam, not the boiler, is affected.

From these considerations it becomes evident that the economy of high steam pressure operation has been attained satisfactorily through the application of heat-transformer evaporators when a large percentage of makeup would otherwise have to be fed into the boiler water system. The examples given have been chosen as typical of the progress made and will serve as an indication of the increasing field of usefulness for evaporator equipment.

CIRCULATION IN BOILER TUBES

By KURT TOENSFELDT
Combustion Engineering Company, Inc.

The curves, representing densities, velocity heads, available heads and losses, as well as velocity and weight ratios, show the trends to be encountered and will serve as a guide in analyzing the circulation within a water tube boiler.

WHILE the circulation in boiler tubes or tubes which line the walls of a furnace has been the subject of discussion from time to time, it is of interest to survey further the influences on the circulation of a water wall or boiler circuit by variations in steam pressure.

In this study a simple circuit is assumed, consisting of a tube exposed to a given heat input which remains constant; also that there is a mixture of steam and water at the outlet end of the tube which remains constant and that the mixture contains a sufficient percentage by volume of water to insure the tube against injury by overheating. Other assumptions are that the amount of tube surface exposed to heat absorption remains the same and that the circuit into which the tubes are connected, including downcomers and risers, remains the same in cross-sectional area, length and number and type of connections.

Variations in flow and resistance within the circuit will then be wholly responsive to the influences caused by steam pressure changes. The head of water available for circulation is the difference between the weight of a substantially solid column of water in the downcomers and the summation of the weights of water and steam mixtures in the heated tubes and the risers therefrom. Density in the downcomer with variation in pressure is shown in Fig. 1 by the curve marked D_d and the density of steam by the curve marked D_{st}. For an arbitrarily assumed value of the percentage by volume of water at the exit end of the tubes exposed to heat, the variation in density of the mixture is shown in Fig. 1 by curve marked D_e and the average density within the tubes is shown by curve marked D_a. All of these curves meet

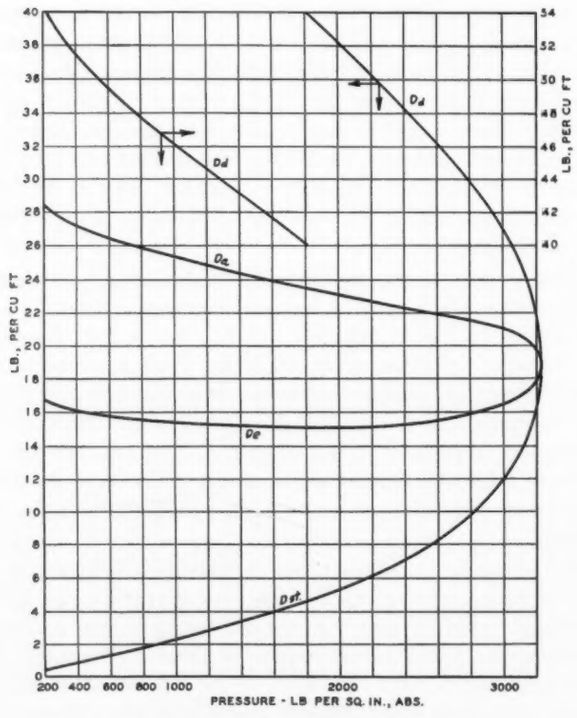

Fig. 1—Curves showing densities

Note that the scale applying to curve D_d, upper left, is at the right, and that applying to the continuation of D_d, upper right, is at the left, as indicated by the arrows.

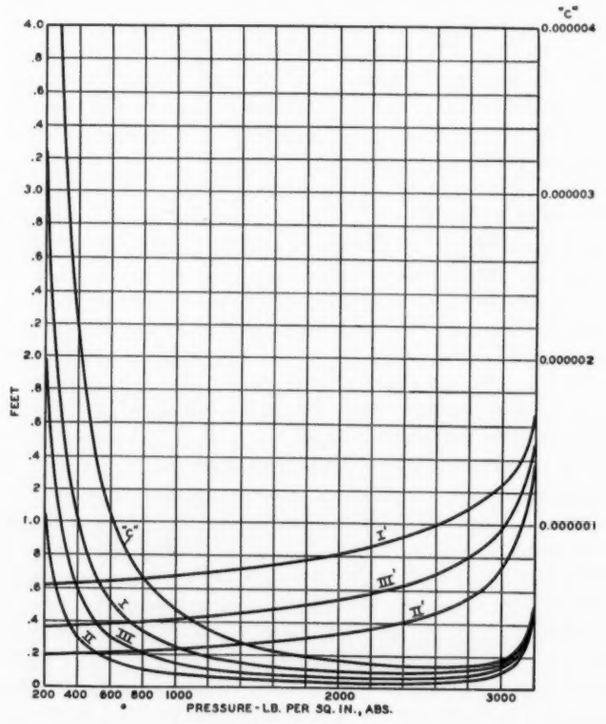

Fig. 2—Curves representing velocity heads

Note that the scale applying to curve C is at the right and that applying to the other curves is at the left.

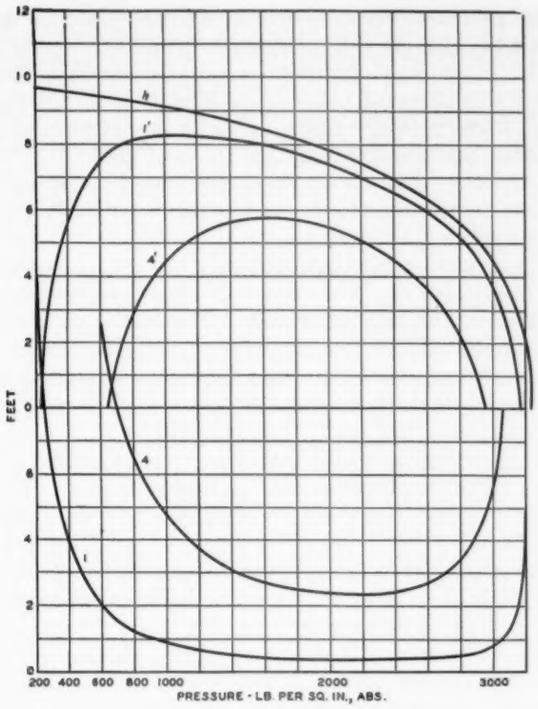

Fig. 3—Available heads and losses

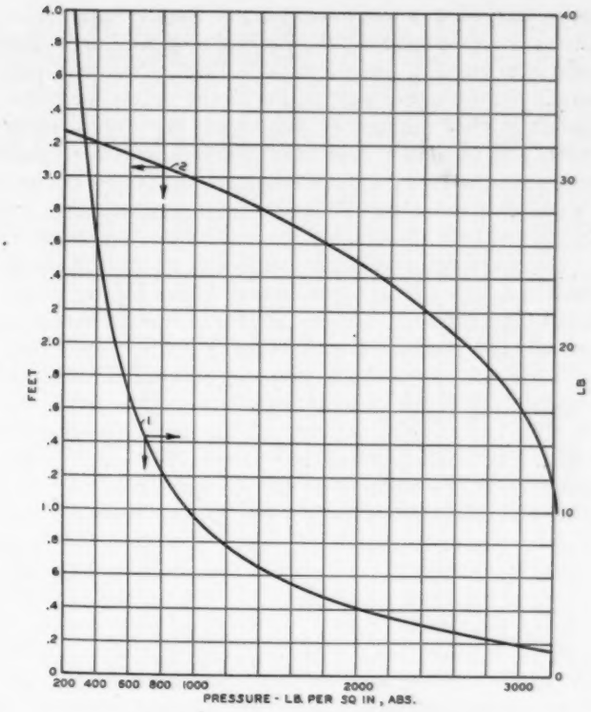

Fig. 4—Velocity and weight ratios

at the critical pressure at a density of approximately 19 lb per cu ft, where steam and water weigh the same. Although D_d, which represents the weight of the downcomer water, drops rapidly with rise in pressure, D_a, which represents the average weight of steam and water mixture in the heated tubes, also drops, while D_e, which represents the weight of the steam and water mixture in the risers, remains almost constant. The resultant available head for an assumed circuit is shown in Fig. 3, by curve *h*.

For a balanced condition of circulation, the head available for circulation equals the sum of all losses in the circuit. These losses vary directly with the velocity heads in the various parts of the circuit, which are proportional to the squares of the velocities in those parts and the velocities in turn are inversely proportional to the densities of the mixtures in those parts and directly proportional to the volume of steam generated by the heated tubes.

The volume of steam generated is dependent upon the heat absorbed by the tube, which in this case is assumed as a constant amount, multiplied by the ratio of the cubic feet of steam per pound to the latent heat of the steam per pound. This last ratio is then the determining influence on the volume of steam generated for the various pressures and its extent may be visualized by the curve marked *C* in Fig. 2. The velocity heads for the average mixture in the heated tube, for the water entering the tube and for the mixture leaving the tube, are directly proportional to curves marked *I'*, *II'* and *III'*, respectively, in Fig. 2, multiplied by the values from curve *C* for the corresponding pressures. The velocity heads in the risers and downcomers will be, respectively, the same as those leaving and entering the heated tubes, if the internal areas of the risers and downcomers are the same as those of the tubes and, if not, they will vary as the squares of the ratios of the heated tube areas to the riser and downcomer areas, respectively.

For comparison, first assume all areas to be the same. It will be seen that for the range of pressures customarily used, the values of *C* predominate in determining the characteristic curves for the velocity head. Such characteristic curves are shown in Fig. 2, marked *I*, *II* and *III*, and the velocity heads assume the general shape of curve *C*. These curves are constructed by multiplying the values of *I'*, *II'* and *III'* by *C* times a constant which involves an assumed constant rate of heat input to the heated tube.

In Fig. 3 the losses of a simple circuit are shown in the curve marked *1* and represent the sum of the products of the appropriate unit losses by the values of curves *I*, *II* and *III* of Fig. 2. For the curve marked *1*, the circuit contains the same area of downcomer tubes as that of the heated tubes, the latter discharging directly into a steam and water drum from which the downcomers are supplied. Note that the characteristic is principally determined by curve *C* of Fig. 2, and that the losses are substantially constant for the higher pressures. In the upper portion of Fig. 3 curve *h* shows the head of water available for circulation in the assumed circuit for the various steam pressures. Note, also, that the available head *h* stands up well into the higher pressures and then drops abruptly to zero at the critical pressure. Below the curve *h*, is shown the difference between this available head in feet and the total losses in feet head of curve *1* below; this is marked *1'*. As the pressures rise the two heads first balance at about 230 lb, followed by a rapid rise in excess head available which remains over the major range of pressures and then rapidly drops, again balancing the two heads at about 3170 lb. The figure shows that for the circuit being considered circulation is more easily provided for pressures above 800 lb than for below.

To investigate the influence of an increased resistance when less downcomer area is used than that in the heated tubes, the ratio of tube area to downcomer area was taken as 4, in the circuit being considered. The

curve marked *4* in the lower part of Fig. 3 shows the resulting losses which again maintains a similar characteristic to curve *C* but for a more limited range of pressures. In the upper part of Fig. 3 the curve marked *4'*, similar to that marked *1'*, represents the difference between the available head and the losses in feet head. Note that the two points of balanced heads now occur at about 700 lb and about 2950 lb, a more limited range, and the curve again rises high between these two points.

It is of interest to review the flow of water and steam-water mixture through the heated tubes for the conditions of the assumed circuit. In Fig. 4 the curve marked *1* shows the pounds of water entering the heated tubes for each pound of steam leaving the tubes and that marked *2* shows the ratio of the velocity of the mixture at the tube exits to the velocity of the water entering the tubes. Note how each of these curves drops, accounting for the drop in resistance as the pressures rise.

All the calculations for the curves are based on theoretical analyses and apply to a single circuit in which distribution of water to the tubes of the circuit and the heat input are uniform throughout. The curves, however, disclose the broad trends to be encountered and the analyses may serve as a guide in calculating boiler design when coupled with experience. Also the velocity of the water and steam at the tube exit are assumed the same. This is not a strictly true assumption which may be checked by referring to "Experiments Regarding Circulation in Vertical-Tube Boilers" by Dr.-Ing. Ernst Schmidt, in COMBUSTION for August 1933. The average speed of the steam bubble in relation to the water (the bubble runs ahead of the water) causes the steam content of the mixture to diminish. Therefore, the losses based on equal velocity of steam and water will be high and on the safe side.

Requirements for an Engineer*

By JOHN M. DRABELLE†

What are the requirements, which when met, make a man a successful engineer? The Society for the Promotion of Engineering Education made a comprehensive, thorough and detailed study of a large group of engineers, electrical, mechanical, civil and chemical, to see just what "stuff" they were made of, and what had caused some of them to go ahead in their profession. Strange and startling as it may seem, from men essentially educators, comes the report that technical knowledge and advanced learning were not large factors in the success of these men.

The greatest essential after you have a thoroughgoing knowledge of your life's chosen work is ability to convey that knowledge to others and to get them to work for and with you, and further, to maintain discipline in your organization not by the fear of dismissal or lay-off but by commanding the respect of those who work for you.

Once a power plant is designed and the equipment purchased and installed, its inherent efficiency, that has been built into it by the designing engineers and the designers of the equipment, becomes a fixed and rigid thing. Above this inherent efficiency is that gain in efficiency which is the result of the ability and the interest of the men that operate and maintain the equipment. It is in that territory that the larger savings and improvements in power station operation and continuity of service are really made and brought about.

A basic requirement is, of course, a thorough knowledge and understanding of your work. The men under you are a jury, and the judgment of five to twelve men of their "boss" is a very accurate one. If you want to get the number of a man, go on a fishing or a hunting trip with him. If there is any meanness in him, the first and not later than the second portage will bring it all out. In other words, your men have your number. Don't try to run a bluff because you can't get away with it. When you don't know, don't try to get away with something, it is far better to say, "I don't know, but I will look it up."

The next basic requirement in dealing with your men is to be absolutely honest and sincere. If you have something to say personally to a man, and he has pulled a "boner," don't bawl him out in front of a group of his fellow employees, but call him into the office and have a friendly heart-to-heart talk with him.

In dealing with men where disciplinary action is required, the rule of rigid honesty and fairness is absolutely essential. A man must be judicially minded, and as he weighs the merits of an engineering proposition, so he must weigh the merits of the stories, oftentimes conflicting, of his men. When something happens, it is well to hear the stories first at an open hearing giving every man a chance to tell his story, and then to review the stories individually with the men involved privately. It is further a good rule after you have heard all that there is to hear, to let the matter rest for twenty-four to forty-eight hours, and then again check a little further (accused and accusers) if it is necessary before rendering a decision. Hasty decisions are generally incorrect and faulty ones.

Remember that in most cases your superior officer is not a technically trained man but a business man running a business, that the power station is but one of several component parts. When submitting a report dealing with an improvement large or small that will require the expenditure of money, reduce that report covering improvements in efficiency, to one giving the reduction in operating expenses in dollars.

Be a good "housekeeper." A clean, neat and orderly power station is invariably an efficiently operated one. Dirt, mess and disorder are invariably the sign of high operating costs and a disgruntled and dissatisfied crew. A clean and neat power station is also always a safe place to work. The banker that loans money to keep the wheels of industry turning knows nothing about boilers and turbines, it is true, but he does read a balance sheet and he does value neatness and order.

Since 1932 much water has flowed under many bridges in respect to State and Federal regulation of labor. The so-called Social Security Act and various other labor acts that have been passed by Congress and State Legislature are examples. Dealing and handling of men will in the future be a considerably different problem than that which it has been in the past and natural leaders of men will be at a premium with employers.

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* From a talk before the National Association of Power Engineers at Cedar Rapids, Ia.

† Mechanical and Electrical Engineer, Iowa Electric Light and Power Company.

WEST VIRGINIA COALS— Their Classification and Analyses

By P. B. PLACE
Combustion Engineering Company, Inc.

This is the concluding article of the series, covering coals from the principal coal-producing areas in the United States. These include Ohio, Kentucky, Virginia, Illinois, Indiana, Pennsylvania, Tennessee, Maryland, Alabama, Missouri, Kansas and West Virginia coals. Typical analyses are given for the coals of the different seams and they are identified by county and trade names. Knowing the source of a given coal, the moisture and ash content, a reasonably close analysis may be determined from the values given in the tables.

WEST VIRGINIA is at present the leading producer of bituminous coal in the United States with an annual output of nearly a hundred million tons. Its nine thousand square miles of coal-bearing rocks contain over a hundred coal seams, half of them minable. As shown in Table I, over a quarter of the total bituminous production in this country comes from this state and about ninety per cent of this is shipped out of the state.

Although nearly all of the counties in the state have coal deposits, eighty-five to ninety per cent of the production comes from the dozen counties listed in Table II. McDowell, Logan, Raleigh and Fayette counties are the principal producers and together contribute over fifty per cent of the state's output.

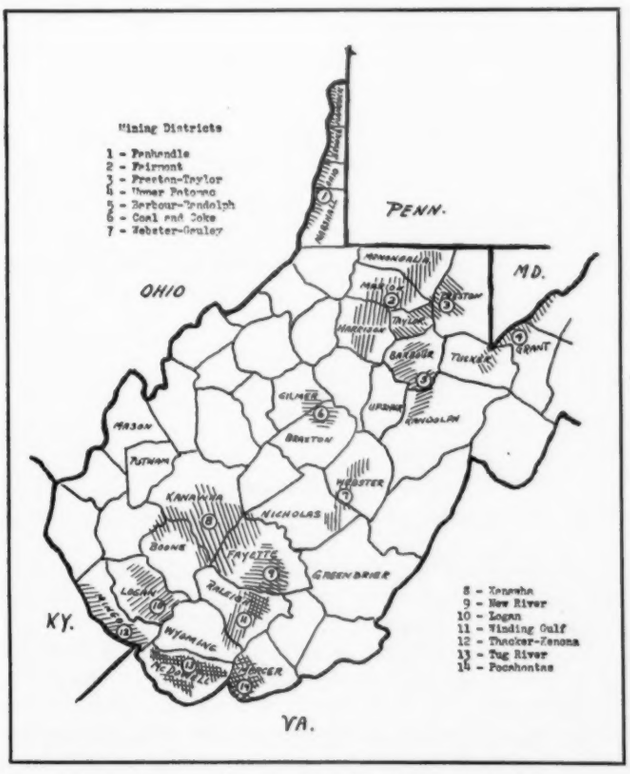


Fig. 1—Location of West Virginia coal fields

TABLE I

Relative Production of Principal Bituminous Coal Producing States in Recent Years

	1929	1930	1931	1932	1933	1934
West Virginia	25.9	26.0	26.5	27.7	28.3	27.3
Pennsylvania	26.8	26.6	25.6	24.1	23.8	25.0
Illinois	11.3	11.5	11.6	10.8	11.2	11.5
Kentucky	11.3	11.0	10.5	11.4	10.8	10.7
Ohio	4.4	4.8	5.3	4.5	5.9	5.8
Indiana	3.4	3.5	3.7	4.3	4.1	4.1
Alabama	3.4	3.3	3.1	2.5	2.6	2.5
Virginia	2.4	2.3	2.5	2.5	2.5	2.6
	88.9	89.0	88.8	87.8	89.2	89.5

TABLE II

Relative Production in Principal Producing Counties in West Virginia

	1929	1930	1931	1932	1933	1934
McDowell	15.4	17.2	16.3	15.5	17.0	17.5
Logan	14.3	14.6	15.2	15.4	14.5	13.6
Raleigh	11.4	12.0	13.3	13.9	13.0	13.0
Fayette	9.5	9.8	10.7	11.0	10.7	11.3
Marion	6.7	6.1	6.8	5.7	7.4	7.1
Kanawha	5.1	5.2	4.8	5.3	5.3	5.9
Monongalia	6.1	6.0	5.5	5.7	5.1	5.0
Mercer	3.0	3.3	3.3	3.6	3.6	3.4
Mingo	4.4	4.4	3.9	3.4	3.4	3.3
Harrison	4.4	4.3	3.7	3.8	3.3	3.2
Boone	2.5	2.5	2.4	2.6	2.5	2.7
Ohio	1.8	1.8	1.6	2.1	2.3	2.1
	87.6	87.2	87.5	88.0	88.1	88.1

As in the other states, the producing area is divided into a number of mining districts. The principal districts, listed roughly in order of their production, are given in Table III together with the counties involved and the principal seams mined. Fig. I shows the general location of these districts. The Fairmount, Pocahontas, Kanawha, Logan and New River districts produce over sixty per cent of the total output of the state.

The coals of West Virginia range from the famous low-volatile, semi-bituminous, bunker fuels of the Pocahontas

type to high-volatile gas coals of the Pittsburgh type. Geologically their classification is similar to that of Pennsylvania coals. Table IV gives an outline of this classification with the principal producing seams underlined. The principal difference between Pennsylvania coals and those of West Virginia is that the bulk of the latter are from the older and deeper Pottsville rocks while the Alleghany and Monongahelia coals constitute the bulk of the Pennsylvania production.

TABLE III

Principal Mining Districts in West Virginia

Mining District	Counties Involved	Principal Seams
Fairmount	Marion Harrison Monongalia	Pittsburgh
Pocahontas-Tug River	McDowell Mercer	Pocahontas No. 3 Beckley Sewell Welch
Kanawha	Kanawha Raleigh (n) Fayette (w) Boone	Winifrede Eagle No. 2 Gas No. 5 Block
Logan	Logan	Cedar Grove Chilton Eagle
New River	Fayette (e) Raleigh (n) Greenbrier	Sewell Fire Creek Beckley
Winding Gulf	Raleigh (e) Wyoming (e)	Beckley Pocahontas No. 3 Sewell
Thacker-Kenova	McDowell (w) Mingo	Cedar Grove Winifrede No. 2 Gas
Panhandle	Brooke Ohio Marshall	Pittsburgh
Preston-Taylor	Preston Taylor (e)	Upper Freeport Pittsburgh
Upper Potomac	Tucker Grant Mineral	Upper Freeport Upper Kittanning Pittsburgh
Randolph-Barbour	Randolph Barbour	Pittsburgh Upper Kittanning
Coal and Coke	Gilmer Braxton	Pittsburgh
Webster-Gauley	Webster Nicholas	Sewell Eagle

As in most other states, there is a multiplicity of classification and trade names from the various seams. Some of the principal alternate names are given in Table IV. Often these alternate names are of local significance, as for example, the Cedar Grove seam is generally known as the Island Creek in Logan county, and as the Red Jacket in Mingo county. Similarly, the Sewell seam is known as the Davy in the Tug River district, the No. 2 Gas seam as the Pond Creek in Mingo county, and the Beckley seam as the War Creek in McDowell county.

West Virginia coals have an enviable reputation for their quality. The lower volatile Pocahontas, Sewell, Beckley and Fire Creek coals from the Pocahontas, New River, Tug River and Winding Gulf districts in McDowell, Raleigh, Fayette and Mercer counties are the so-called smokeless fuels of the state. They are standard bunker fuels and in great demand for steam raising and for export. These coals are also used for making coke and as general industrial and domestic fuels. The higher volatile Pittsburgh, Cedar Grove, Chilton, No. 2 Gas, Eagle, Winifrede, Coalburg, Freeport and Kittanning coals from the Fairmount, Kanawha, Logan, Thacker and Panhandle districts are excellent coke and gas fuels and widely used as steam, railway, industrial and domestic fuels.

Physically, the lower volatile coals are soft and easily crushed. They have a low moisture, ash and sulphur content, a refractory ash and a heat value between 15,600 and 15,800 Btu per lb on a "moisture- and ash-free" basis. They may be burned on underfeed stokers or in pulverized form, ignite easily and burn with a relatively short flame.

The higher volatile coals are harder and vary in physical characteristics. The Pittsburgh seam in the northern Fairmount region yields a strong hard blocky coal that is excellent fuel for railway and domestic use. The Kittanning seam, though soft in the northern part of the state, changes to a hard blocky coal in the southern district that is known as No. 5 Block. In the Kanawha district much of the coal is splint, but not as hard as similar coals in eastern Kentucky. In general, the Pittsburgh, Freeport and Kittanning seams have medium fusible ash and the high-volatile coals of the Pottsville group have a refractory ash of high fusion temperature.

TABLE IV

Geological Classification
of Principal Coal Bearing Rocks
and Principal Coal Seams in
West Virginia

I. Pennsylvanian Series
  a. Monongahelia Formation
    1. Waynesburg
    2. Uniontown
    3. Sewickley (Waynetown)
    4. Redstone
    5. Pittsburgh
  b. Conemaugh Formation
    1. Elk Lick
    2. Bakerstown
  c. Alleghany Formation
    1. Upper Freeport (Davis)
    2. Lower Freeport
    3. Upper Kittanning
    4. Middle Kittanning
    5. Lower Kittanning (No. 5 Block)

II. Pottsville Series
  a. Upper Kanawha Group
    1. Stockton-Lewiston (Belmont)
    2. Coalburg (Buffalo Creek)
    3. Winifrede (Dorothy) (Black Band)
  b. Lower Kanawha Group
    1. Chilton
    2. Williamson
    3. Cedar Grove (Island Creek) (Thacker)
    4. Alma (Peerless)
    5. No. 2 Gas (Campbell Creek) (War Eagle) (Pond Creek)
    6. Powellton
    7. Eagle (No. 1 Gas)
    8. Gilbert (Jawbone)
  c. New River Group
    1. Laeger (Bradshaw)
    2. Sewell (Davy)
    3. Welch (Tug River)
    4. Beckley (War Creek)
    5. Fire Creek (Quinnimont)
  d. Pocahontas Group
    1. Pocahontas No. 6
    2. Pocahontas No. 4
    3. Pocahontas No. 3 (Thick Vein)

In Tables V and VI are given typical individual analyses of the principal seams in different counties. The moisture and ash values are given on an "as received" basis and the other values are on a "moisture- and ash-free" basis. These analyses indicate the normal variations that may be expected in analyses from the same seam in the same

TABLE V

Typical Individual Analyses of Low Volatile Coals of West Virginia

As Received				Moisture and Ash Free					
Moisture	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu/lb
Pocahontas No. 3									
McDowell County									
1.9	5.4	16.7	82.3	0.8	4.4	91.1	1.2	2.5	15700
2.6	4.8	17.7	82.3	0.8	4.4	91.1	1.2	2.5	15720
3.0	4.6	15.0	85.0	0.5	4.6	90.7	1.2	3.0	15760
3.8	3.2	19.7	80.3	0.6	4.6	90.0	1.3	2.6	15800
2.0	3.9	19.7	80.3	0.5	4.7	90.7	1.2	2.9	15750
1.5	7.3	20.3	79.7	1.1	4.6	90.6	1.2	2.5	15720
3.5	5.4	23.4	76.6	0.6	4.9	90.5	1.3	2.7	15730
3.5	5.3	24.1	75.9	0.7	4.9	90.5	1.2	2.7	15700
2.9	3.0	22.0	78.0	0.5	4.8	90.4	1.3	3.0	15750
Mercer County									
3.4	4.1	15.8	84.2	0.7	4.8	90.6	1.2	2.7	15790
2.9	3.7	15.0	85.0	0.6	4.7	90.5	1.2	3.0	15870
3.6	3.6	15.5	84.5	0.8	4.5	91.5	1.3	1.8	15810
2.0	4.5	20.5	79.5	0.6	4.6	90.9	1.3	2.6	15760
3.2	3.3	20.5	79.5	0.5	4.6	91.1	1.2	2.5	15740
2.6	4.3	20.6	79.4	0.6	4.6	90.5	1.2	3.1	15690
Wyoming County									
2.9	5.4	19.3	80.7	0.8	4.6	90.7	1.4	2.5	15690
2.3	6.1	18.7	81.3	0.9	4.6	90.6	1.3	2.6	15610
2.1	6.4	19.6	80.4	1.0	4.7	90.6	1.3	2.4	15580
Sewell Seam									
McDowell County									
4.1	3.8	16.5	83.5	0.7	4.6	90.7	1.5	2.5	15820
3.6	4.2	15.5	84.5	0.7	4.7	89.8	1.4	3.4	15800
3.5	3.2	16.0	84.0	0.6	4.5	90.4	1.5	3.0	15850
2.7	3.4	20.4	79.6	0.7	4.7	90.2	1.5	2.9	15780
2.9	4.2	19.8	80.2	1.1	4.7	90.6	1.6	2.0	15750
Raleigh County									
4.9	3.0	16.5	83.5	0.9	4.9	89.4	1.5	3.3	15720
4.2	3.6	15.4	84.6	0.7	5.0	89.9	1.6	2.8	15770
5.1	3.7	18.5	81.5	0.9	5.0	89.5	1.7	2.9	15750
2.2	4.6	21.4	78.6	1.2	4.8	89.6	1.8	2.6	15680
2.7	3.9	22.9	77.1	1.0	4.8	89.2	1.8	3.2	15660
2.8	4.7	23.7	76.3	2.5	4.8	88.5	1.8	2.4	15560
Fayette County									
4.5	4.7	18.7	81.3	1.0	5.0	89.6	1.5	2.9	15670
2.6	5.1	19.7	80.3	1.4	5.0	89.6	1.5	2.5	15720
3.3	3.7	18.7	81.3	0.9	4.9	89.4	1.6	3.2	15690
2.7	4.7	23.6	76.4	0.9	4.9	89.6	1.7	2.9	15680
3.7	2.5	24.5	75.5	0.6	5.0	88.6	1.6	4.2	15550
3.4	2.2	23.9	76.1	0.6	5.0	89.1	1.8	3.5	15690
Beckley Seam									
Raleigh County									
2.7	2.6	19.2	80.8	0.9	4.6	90.3	1.7	2.5	15670
2.9	2.8	18.0	82.0	0.6	4.7	91.1	1.6	2.0	15630
3.1	4.7	18.9	81.1	0.8	4.7	90.6	1.6	2.3	15710
Wyoming County									
2.2	4.4	20.0	80.0	1.3	4.6	89.8	1.5	2.8	15700
2.7	5.7	20.0	80.0	1.5	4.6	90.2	1.4	2.3	15740
2.7	3.7	19.6	80.4	1.0	4.7	90.0	1.6	2.6	15660
McDowell County									
2.6	8.2	19.3	80.7	0.6	4.7	90.4	1.6	2.7	15710
2.2	8.9	19.5	80.5	0.7	4.6	90.4	1.5	2.8	15700
2.2	8.4	18.3	81.7	0.8	4.4	90.3	1.6	2.9	15670
Fire Creek Seam									
Raleigh County									
2.5	4.8	17.6	82.3	1.1	4.5	90.9	1.4	2.1	15680
1.6	5.4	17.9	82.1	0.9	4.6	90.6	1.4	2.5	15650
2.0	6.8	17.7	82.3	1.0	4.6	90.6	1.4	2.4	15700
Fayette County									
3.1	4.9	18.3	81.7	0.6	5.1	89.2	1.5	3.6	15770
3.3	6.7	17.3	82.7	1.0	5.0	89.6	1.6	2.8	15720
3.6	6.2	18.7	81.3	0.7	5.0	89.8	1.7	2.8	15750

TABLE VI

Typical Individual Analyses of Medium and High Volatile Coals of West Virginia

As Received				Moisture and Ash Free					
Moisture	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu/lb
Pittsburgh Seam									
Marion County									
2.3	6.7	41.4	58.6	2.4	5.8	84.5	1.6	5.7	15170
2.6	8.7	40.5	59.5	2.3	5.6	84.2	1.4	6.5	15230
2.5	6.6	41.4	58.6	1.3	5.7	84.3	1.7	7.0	15150
Monongalia County									
1.3	6.5	38.8	61.2	2.5	5.2	82.1	1.4	8.8	15150
0.9	5.6	40.8	59.2	2.0	5.4	82.5	1.5	8.6	15260
4.5	6.4	39.0	61.0	2.0	5.5	82.5	1.5	8.5	15290
Harrison County									
1.4	6.1	42.0	58.0	3.6	5.3	83.2	1.3	6.6	15000
0.9	7.9	44.0	56.0	4.6	5.4	82.7	1.4	5.9	14920
1.8	5.3	40.7	59.3	2.4	5.4	82.8	1.4	8.0	15040
Brooke County									
4.4	8.1	42.7	57.3	3.0	5.5	82.4	1.7	7.4	14790
4.2	9.5	42.3	57.7	3.2	5.7	81.6	1.7	7.8	14850
3.8	7.7	42.5	57.5	1.9	5.5	82.6	1.6	8.4	14830
Winifrede Seam									
Kanawha County									
1.7	6.8	38.6	61.4	0.8	5.1	83.4	1.3	9.4	15060
1.8	7.1	38.6	61.4	0.6	5.0	84.1	1.3	9.0	15170
0.9	3.9	36.1	63.9	0.7	4.8	85.4	1.4	7.7	15030
Mingo County									
5.0	10.3	39.9	60.1	1.0	5.4	84.0	1.8	7.8	14810
4.2	6.8	41.9	58.1	0.8	5.5	84.8	1.7	7.4	14960
No. 2 Gas Seam									
Kanawha County									
1.0	5.4	30.4	69.6	2.2	5.8	84.5	1.2	6.3	15350
1.5	5.2	30.7	69.3	1.0	5.6	84.8	1.1	7.5	15560
1.0	9.5	32.7	67.3	1.7	5.8	84.1	1.1	7.3	15250
0.3	6.6	37.7	62.3	1.8	5.3	83.5	1.0	8.4	15280
1.4	5.0	39.4	60.6	1.5	5.3	82.2	1.5	9.5	15070
1.3	6.6	39.8	60.2	0.8	5.5	84.5	1.6	7.6	15330
Fayette County									
2.6	3.6	34.3	65.7	1.0	5.4	87.3	1.6	4.7	15450
2.3	4.0	33.4	66.6	0.8	5.4	88.8	1.6	3.4	15350
1.8	6.8	35.5	64.5	2.4	5.4	86.0	1.5	4.7	15390
Logan County									
3.0	5.9	35.5	64.5	0.7	5.4	86.5	1.6	5.8	15350
3.2	5.0	36.3	63.7	0.8	5.5	86.0	1.6	6.1	15320
Mingo County									
2.4	4.3	35.2	64.8	0.8	5.1	85.6	1.6	6.9	15350
3.2	5.6	34.4	65.6	1.3	5.2	87.0	1.8	4.7	15400
3.7	3.6	36.2	63.8	0.7	5.5	86.1	1.7	6.0	15120
Chilton Seam									
Logan County									
1.5	7.5	38.2	61.8	0.8	5.6	85.1	1.7	6.8	15250
2.5	6.5	41.9	58.1	0.7	5.8	84.2	1.4	7.9	15140
0.8	6.3	37.4	62.6	1.1	5.6	85.9	1.6	5.8	15200
Cedar Grove Seam									
Logan County									
2.8	5.7	38.1	61.9	1.4	5.5	85.9	1.6	5.6	15360
3.0	5.2	35.8	64.2	0.8	5.5	86.9	1.6	5.2	15500
1.7	5.5	35.4	64.6	1.0	5.4	85.1	1.4	7.1	15220
Mingo County									
2.4	6.3	37.7	62.3	1.0	5.4	85.4	1.7	6.5	15240
1.4	3.7	37.8	62.2	0.8	5.5	84.3	1.4	8.0	15420
2.1	7.5	39.9	60.1	1.8	5.3	84.6	1.7	5.6	15250
Eagle Seam									
Fayette County									
2.4	4.6	34.1	65.9	1.7	5.2	85.8	1.2	6.1	15550
2.9	4.9	32.2	67.8	1.2	5.3	87.3	1.6	4.6	15430
Lower Kittanning Seam									
Kanawha County									
3.4	9.5	41.1	58.9	1.2	5.6	84.1	1.6	7.4	14960
2.3	6.7	40.9	59.1	2.0	5.3	82.4	1.5	8.8	14970
1.3	6.7	38.3	61.7	1.4	5.4	81.2	1.2	10.8	14800
Preston County									
3.0	15.7	29.6	70.4	3.7	5.1	86.2	1.7	3.3	15340
3.7	11.5	27.6	72.4	2.4	5.2	87.3	1.7	3.4	15490
Upper Freeport Seam									
Monongalia County									
1.6	7.9	31.4	68.6	1.1	5.3	86.5	1.4	5.7	15310
Preston County									
1.4	9.3	29.6	70.4	1.7	5.2	87.2	1.6	4.3	15460
3.6	8.9	33.6	66.4	1.8	5.5	86.1	1.6	5.0	15440

TABLE VII

Average Analyses of West Virginia Coals in Principal Producing Counties

As Received				Moisture and Ash Free					
Moisture	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu/lb
McDowell County									
Pocahontas No. 3 Seam									
2-3	4-6	15.4	84.6	0.6	4.6	90.9	1.2	2.7	15785
Pocahontas No. 4 Seam									
1-3	4-6	17.7	82.3	0.7	4.6	90.6	1.3	2.8	15785
Beckley (War Creek) Seam									
2-3	8-11	19.1	80.9	1.0	4.6	90.1	1.6	2.7	15650
Sewell (Davy) Seam									
2-4	3-5	15.9	84.1	0.7	4.6	90.3	1.5	2.9	15865
2-4	3-5	20.8	79.2	0.8	4.7	90.2	1.5	2.8	15750
Welch Seam									
2-3	5-9	17.1	82.9	0.6	4.7	90.4	1.4	2.9	15710
Logan County									
Cedar Grove (Island Creek) Seam									
1-3	5-7	37.1	62.9	1.1	5.5	85.4	1.5	6.5	15300
Chilton Seam									
1-3	3-6	38.7	61.3	0.8	5.4	85.1	1.5	7.2	15215
No. 2 Gas (Cannbell Creek) Seam									
2-4	5-7	35.9	64.1	0.7	5.5	86.3	1.6	5.9	15335
Raleigh County									
Beckley Seam									
2-4	2-6	18.4	81.6	0.7	4.7	90.4	1.6	2.6	15680
Fire Creek Seam									
2-3	2-6	17.7	82.3	0.9	4.7	90.3	1.5	2.6	15705
Pocahontas No. 3 Seam									
2-3	4-5	17.4	82.6	0.9	4.6	90.8	1.3	2.4	15590
Sewell Seam									
3-5	2-4	18.9	81.1	0.9	4.9	89.6	1.6	3.0	15710
Fayette County									
Fire Creek Seam									
2-4	4-7	18.7	81.3	0.7	5.0	89.6	1.6	3.1	15710
Sewell Seam									
2-4	2-5	23.1	76.9	0.8	5.0	88.9	1.7	3.6	15625
No. 2 Gas Seam									
2-3	4-6	34.7	65.3	1.1	5.4	87.1	1.6	4.8	15425
Eagle Seam									
2-3	4-6	33.5	66.5	1.0	5.5	86.9	1.6	5.0	15530
Marion, Brooke and Harrison Counties									
Pittsburgh Seam									
2-3	6-8	41.5	58.5	2.0	5.6	83.7	1.6	7.1	15000
Kanawha County									
Winifrede Seam									
1-2	3-7	35.5	64.5	0.3	5.1	84.5	1.3	8.3	15155
No. 2 Gas Seam									
1-2	3-7	34.0	66.0	1.4	5.4	84.4	1.2	7.6	15335
Coalburg Seam									
1-3	5-8	37.8	62.2	0.9	5.5	83.8	1.3	8.5	15220
No. 5 Block Seam									
1-3	5-8	40.9	59.1	1.3	5.3	82.3	1.4	9.7	14970
Monongalia County									
Pittsburgh Seam									
1-4	5-8	38.8	61.2	2.7	5.3	83.8	1.4	6.8	15380
Upper Freeport									
1-3	7-12	33.7	66.3	1.	5.1	84.4	1.3	8.2	15235
Mercer County									
Pocahontas No. 3 Seam									
2-4	3-5	19.6	80.4	0.7	4.6	90.7	1.2	2.8	15760
2-4	3-5	15.2	84.4	0.7	4.7	90.6	1.2	2.8	15810
Mingo County									
Winifrede Seam									
4-5	6-9	40.9	59.1	0.9	5.4	84.4	1.7	7.6	14880
Coalburg Seam									
2-4	4-10	39.5	60.5	0.9	5.2	84.0	1.3	8.6	14915
Cedar Grove Seam									
1-3	4-6	37.9	62.1	1.0	5.4	85.4	1.4	6.8	15360
Marshall and Ohio County									
Pittsburgh Seam									
3-5	7-12	46.3	53.7	4.7	5.6	31.0	1.5	7.2	14820
Boone County									
No. 2 Gas Seam									
1-3	4-7	40.2	59.8	1.1	5.4	85.3	1.4	6.8	15260

TABLE VIII

TYPICAL AVERAGE ANALYSES OF WEST VIRGINIA COALS

1. Low Volatile Coal
Pocahontas No. 3, Sewell, Beckley and Fire Creek Seams - McDowell, Raleigh, Fayette and Mercer Counties

	As Received	Dry	Moisture and Ash Free
Moisture	2.5	-	-
Ash	5.0	5.13	-
Volatile Matter	17.11	17.55	18.5
Fixed Carbon	75.39	77.32	81.5
	100.00	100.00	100.0
Sulphur	0.74	0.76	0.8
Hydrogen	4.35	4.46	4.7
Carbon	83.53	85.67	90.3
Nitrogen	1.29	1.33	1.4
Oxygen	2.59	2.65	2.8
	92.50	94.87	100.0
Btu per lb.	14545	14920	15725

2. Medium Volatile Coal
Freeport and Kittanning Seams Preston, Monongalia Counties

	As Received	Dry	Moisture and Ash Free
Moisture	3.0	-	-
Ash	9.0	9.28	-
Volatile Matter	25.40	27.22	30.0
Fixed Carbon	61.60	63.50	70.0
	100.00	100.00	100.0
Sulphur	1.76	1.81	2.0
Hydrogen	4.66	4.81	5.3
Carbon	76.21	78.56	86.6
Nitrogen	1.41	1.45	1.6
Oxygen	3.96	4.09	4.5
	88.00	90.72	100.0
Btu per lb.	13560	13980	15410

3. High Volatile Coal
Cedar Grove, Chilton, Coalburg, No. 2 Gas and Winifrede Seams - Kanawha, Logan and Mingo Counties

	As Received	Dry	Moisture and Ash Free
Moisture	2.0		-
Ash	6.0	6.12	-
Volatile Matter	34.04	34.73	37.0
Fixed Carbon	57.96	59.15	63.0
	100.00	100.00	100.0
Sulphur	0.92	0.94	1.0
Hydrogen	4.97	5.07	5.4
Carbon	78.20	79.80	85.0
Nitrogen	1.29	1.31	1.4
Oxygen	6.62	6.76	7.2
	92.00	93.88	100.0
Btu per lb	14050	14335	15270

4. High Volatile Coal
Pittsburgh Seam
Marion, Monongalia, Harrison and Brooke Counties

	As Received	Dry	Moisture And Ash Free
Moisture	2.5	-	-
Ash	7.0	7.18	-
Volatile Matter	38.39	38.52	41.5
Fixed Carbon	54.11	54.30	58.5
	100.00	100.00	100.0
Sulphur	2.31	2.32	2.5
Hydrogen	5.09	5.11	5.5
Carbon	76.77	77.04	83.0
Nitrogen	1.39	1.39	1.5
Oxygen	6.94	6.96	7.5
	92.50	92.82	100.0
Btu per lb.	13925	13975	15055

county. Where a wide variation in volatile matter is found in the same county, two or three groups of typical analyses are given in order to cover the whole county. It will be noted that a change in volatile, however, does not make a great difference in the analytical values of the rest of the analysis.

In Table VII are given average analyses for the various seams in the principal producing counties. These averages have been prepared from lists of similar individual analyses and in many cases represent a large number of such analyses.

Although no average values are to be preferred to careful analysis of a well taken sample, the data given in Table VII are of value in checking the probable accuracy of a reported analysis and in the absence of specific data, a complete analysis for a given coal may be set up from these values that will be reliable for most purposes. As indicated by the table, it is important to know the source of a coal to establish its analysis. Trade names are of little value except when they may be traced, through some directory such as the Keystone Coal Buyers Manual, to a certain seam and county or mining district. Often trade names are names of towns, creeks or local areas that may be located on a map.

For general purposes, typical analyses of West Virginia coals are given in Table VIII on an "as received," "dry" and "moisture- and ash-free" basis. These are general averages that represent the bulk of the production from this state.

The method of setting up a complete analysis from the "moisture- and ash-free" values in the tables is as follows:

1. Determine the moisture and ash from the coal in question on an "as received" basis.
2. Multiply the "moisture- and ash-free" values in the average analysis by (100–moisture–ash) to get the "as received" analysis. Example: In Table VIII, $100.0-5.0-2.5=92.5$; $\frac{18.5 \times 92.5}{100} = 17.11$ percent volatile matter "as received."
3. Divide the "as received" ash by (100–moisture) to get per cent ash on "dry" basis. Example: In Table VIII, $100-2.5=97.5$; $\frac{5.0 \times 100}{97.5} = 5.13$ per cent ash on a "dry" basis.
4. Multiply the moisture and ash values in the average analysis by (100–ash on dry basis) to get the analysis on a "dry" basis. Example: In Table VIII, $100.0-5.13=94.87$; $\frac{18.5 \times 94.87}{100} = 17.55$ per cent volatile matter on "dry" basis.

THE PRODUCTION OF POWER

The following statistics and excerpts are taken from a chapter on "Power" by Dean A. A. Potter, of Purdue University, and M. M. Samuels, electrical engineer of the Federal Power Commission, in the recently published report of the National Resources Committee on "Technological Trends and National Policy."

THE mechanical power available in this country in 1935 was about 1231 million horsepower distributed as indicated in Table I.

TABLE I—DISTRIBUTION OF POWER IN THE UNITED STATES

Electric central stations	44,670,000
Industrial power plants	20,133,000
Electric railway plants	2,500,000
Isolated non-industrial plants	1,500,000
Mines and quarries	2,750,000
Agricultural prime movers	72,763,000
Automobiles, busses, trucks and motorcycles	965,000,000
Airplanes	3,500,000
Locomotives	88,000,000
Marine	30,000,000
Total horsepower	1,230,816,000

The installed electric generator capacity in this country of nearly 33.5 million kilowatts may be compared with 12.8 million in Germany, 10.1 in France, 7.25 in Great Britain, 6.1 in Canada, 5.47 in Soviet Russia, 5.3 in Japan and 4.55 million kilowatts in Italy. On the per capita basis, the installed generator capacity of the United States is 0.27 kilowatts as compared with 0.19 in Germany, 0.24 in France, 0.16 in Great Britain, 0.59 in Canada, 0.033 in Union of Soviet Socialist Republics, 0.077 in Japan and 0.11 in Italy.

Of the installed generating capacity in electric central stations, fuel prime movers represented, as of December 31, 1935,[1] a total of 24,488,400 kw, or 73.2 per cent and hydroelectric plants, 8,958,000 kw, or 26.8 per cent. Of the fuel prime movers in electric power stations, steam plants represented 98 per cent, and internal-combustion engines 2 per cent. About half a million kilowatts installed capacity in diesel engines was reported in electric generating stations at the end of 1934. More than half of this, or 280,000 kw, was in municipal power plants.

The Federal Power Commission has reported for the year 1935 the capacity of publicly owned hydroelectric plants as 853,000 kw. Of this total 455,000 is represented in municipal plants, 38,000 in the Bureau of Reclamation and 360,000 kw in generating capacity as owned and operated by State and Federal Governments.

The growth of the so-called electric light and power industry is indicated by comparing the output of 92 billion kilowatt-hours in 1935 with 80 billion in 1927, 25.5 billion in 1917, 11.5 billion in 1912, 6 billion in 1907 and only about 2.33 billion kilowatt-hours in 1902.[2] Since 1882 and until 1929 the output of electric central stations has practically doubled every 5.5 years.

The present electric output in this country of over 92 billion kilowatt-hours should be compared with 31 billion in Germany, 20.7 billion in Great Britain, 20.5 billion in Soviet Russia, 19.3 billion in Canada, 18.16 billion in Japan, 15.3 billion in France and 11.9 billion kilowatt-hours in Italy. These figures[3] of electric output on the per capita basis are 678 for the United States, 398 for Germany, 405 for Great Britain, 97 for the Union of Soviet Socialist Republics, 1629 for Canada, 269 for Japan, 356 for France and 265 kilowatt-hours for Italy.

At the beginning of 1935 the electric utility industry consisted of approximately 1620 privately owned operating companies and 1930 municipal systems.

Industrial Power Plants

Industrial plants in 1934 had a generating capacity of about 15,000,000 kw,[4] which is equal to 20,133,000 hp. The generating capacity of industrial power plants increased from 3,411,000 hp in 1880, to 16,803,000 in 1910, to 19,900,000 in 1920, and to about 20,000,000 in 1935.[5]

The Federal Power Commission has made a study of 80 of the largest steam-electric power plants constructed since 1920, to determine the cost per kilowatt of installed capacity. The results of this study are given in Table II.

TABLE II—RELATION OF COST TO CAPACITY OF STEAM-ELECTRIC PLANTS

Price per kilowatt range	Kilowatts capacity	Per cent of total capacity	Number of plants
Under $70	247,000	2.6	4
$70 to $80	1,073,500	11.4	6
$80 to $90	859,500	9.1	8
$90 to $100	822,500	8.7	7
$100 to $110	2,200,000	23.2	15
$110 to $120	977,950	10.4	11
$120 to $130	1,566,750	16.5	11
$130 to $140	934,500	9.8	11
$140 to $150	182,860	1.9	2
$150 and over	602,000	6.4	5

Hydroelectric station costs vary with the topography and geology of the site, water available, needs for storage and auxiliary equipment.

Stationary Steam Power Plants

Our large coal reserves and the efficiency of the steam prime mover indicate that steam power plants will long remain a major factor in the production of mechanical power. In the stationary steam power plant the fixed charges have been going up during recent years while the operating expenses have been going down; yet better engineering has greatly reduced the actual cost per unit of power output from the power plant.

Steam-electric plant economies for 1934, in Btu per kw of net station output, at 60 per cent load factor, are given in the 1936 Interim Report of the National Power Survey of the Federal Power Commission as: 28 per cent of the plants had an economy better than 14,000 Btu; 47.8 per

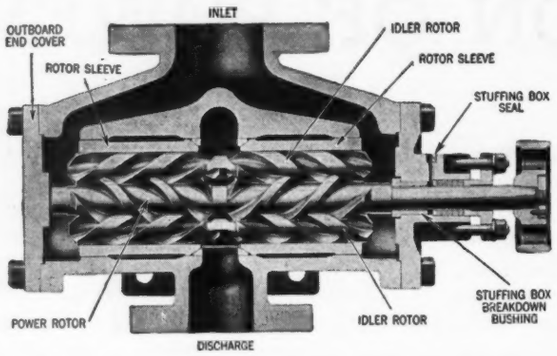
[1] Edison Electric Institute Bulletin, February 1936 (estimates by the Federal Power Commission for 1935 are 34,446,400 kw distributed in the following manner: Private, 31,578,941; municipal, 1,973,446; and Federal and State Government, 467,949 kw). One kilowatt = 1.33 horsepower.

[2] Compiled from figures published in the *Electrical World* and by the Edison Electric Institute.

[3] Supplied by the Federal Power Commission.

[4] Frank F. Fowle before Midwest Power Engineering Conference based the figure of 15,000,000 kw for 1934 upon census statistics for 1929 with minor allowance for growth.

[5] Statistical supplement, N.E.L.A., 1931.



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. . . are readily meeting high temperature conditions without makeshift in design, material or parts. The sound and proven principles of the Vulcan valve operating head, bearings and elements guarantee operating economies which make both the annoyance and cost of frequent servicing unnecessary.

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cent, between 14,000 and 18,000; 15 per cent, between 18,000 and 22,000; 4.8 per cent, between 22,000 and 25,000; 3.1 per cent, 25,000 to 30,000; and only about 1 per cent over 30,000 Btu.

Hydroelectric Plants

The hydroelectric and steam-electric plants are complementary sources of power. There is need for accurate studies to develop the proper proportion of hydro and steam plants in different sections of the country for the most economical power generation. Present low costs of steam plants necessitate discrimination in developing water power sites.

Hydroelectric plants are practical where good water sites are available, not too far from load centers, with well sustained continuous water flow, or with water storage which can be developed at low cost.

In most regions of this country the hydroelectric plant should be considered as complementary to the steam power plant rather than the main power source. Water can supply power in certain localities during peak load periods at low cost per kilowatt-hour.

In many localities, however, absence of fuel cost does not make up for high fixed charges and low reliability of water power. The high efficiency and low fixed charges now possible in large fuel burning plants, place hydroelectric developments at a disadvantage in most sections of the United States if low power cost is the objective. Water power plants, due to their high fixed cost, depend even more than do fuel burning plants upon a high use factor or load factor.

Personals

Frank G. Boyce, formerly manager of electric production and transmission of the Consumers Power Company, has been made vice president of that company. Mr. Boyce, prior to joining the Consumers Power Company about twenty years ago, had been with the Allis-Chalmers Mfg. Company, Stone & Webster and the Milwaukee Electric Railway & Light Company.

T. E. Purcell, general superintendent of power stations of the Duquesne Light Company, Pittsburgh, was elected president of the National District Heating Association at its recent annual meeting in Detroit.

J. Y. Dahlstrand, well-known turbine designer, and formerly associated with the Allis-Chalmers Mfg. Company, the Westinghouse Electric & Mfg. Company and the Kerr Turbine Company, has joined the Ward Leonard Electric Company.

Errata

The article on "Heat Transfer" by J. H. Sengstaken, in the July issue contained three typographical errors. First, the cuts of Figs. 1 and 2 were transposed; secondly, in formula (4) the e should have aligned with $\frac{W_1C_1}{W_2C_2}$; and thirdly, in formula (6) the second equality sign should have been minus. A limited number of corrected reprints are available and copies will be sent to those interested upon request.

Fuels of Today and Tomorrow*

The total energy supplied from mineral fuels in the United States increased from 14,000 trillion Btu in 1907 to 24,600 in 1929, and after a Depression drop, the figure in 1936 was raised to 21,800. Industry and public utility power consumed 45 per cent, transportation about a third and domestic and miscellaneous uses one-fourth of our energy supply. Coal in 1929 constituted 84 per cent of the fuel for domestic and miscellaneous purposes, 73 per cent for industrial use and public utility power, and 57 per cent for transportation; petroleum provided 43 per cent of transportation fuel, including almost 100 per cent of road vehicles and airplane fuel, 73 per cent of marine fuel and 11 per cent of railroad fuel. Natural gas comprised 16 per cent of industrial and public utility power consumption and 7 per cent of the domestic and miscellaneous needs. Since 1929, 7 per cent of the total energy demand has been transferred from anthracite and bituminous coal to petroleum, natural gas and water power.

By ARNO C. FIELDNER

Chief, Technologic Branch,
U. S. Bureau of Mines

THIRTY years ago coal furnished 89 per cent, oil 8 per cent and natural gas 3 per cent of the mineral fuel energy of the United States; water power contributed an equivalent of 3 per cent of the mineral fuels. After the War the displacing effect, first of petroleum then of natural gas, caused a steady decline in the proportion of energy from coal until 1933, the bottom year of the Depression, and at present coal furnishes about one-half of the total energy supply. This decline was augmented by the cumulative effect of research on increasing the efficiency of coal utilization.

Rise of Petroleum

The present age of intense competition of the different fuels has its underlying cause in the last century when Otto invented the gas engine in 1867 and Daimler built the first motor car using gasoline in 1887.

Thirty years ago an annual production of 166 million barrels of oil supplied the world with lamp and lubricating oils and was beginning to force its way to the front as a fuel for steam generation in competition with coal. By 1915 automotive needs for gasoline began to be felt. Prospecting spread to many States and the science of petroleum geology greatly helped in new discoveries. Following the War demand again overtook supply and, as a consequence, 34,000 wells were drilled in 1920 alone and a flood of oil from California and the mid-continent fields replenished the deficit.

In 1926 another shortage alarm appeared. The number of motor vehicles had increased to 22 million and the domestic gasoline supply was again falling behind the demand. New efforts were put forth and deeper drilling to depths exceeding 7000 ft, then to 10,000 ft and more recently to 12,000 ft, as well as the introduction of geophysical methods in finding oil strata, provided new supplies at an increasing rate. In addition, the enormous East Texas pool with 22,000 wells was discovered in 1930 by wildcat methods. Slightly over 1 billion barrels of oil were produced in the United States in 1929 and this figure was duplicated in 1936.

Parallel with the finding of new sources of crude oil, continuous progress was made in increasing the yield and quality of the gasoline produced. We have increased the production ratio of gasoline to crude oil from 13 per cent in 1912 to 44 per cent in 1935. The present average yield of gasoline by cracking is estimated at 60 per cent and each grade of fuel marketed throughout the broad expanse of the United States now has uniform properties.

Another landmark in the improvement of motor fuels was Midgley's and Boyd's discovery, inspired by Kettering, in 1922, that the addition of small quantities of tetraethyl lead and certain other substances to gasoline would suppress detonation and permit the use of higher compression ratios in the engine, thus increasing the efficiency of utilization. So great has been the bromine requirement of the lead anti-knock compounds that it became necessary for chemists to devise a process for extracting the minute quantities of bromine in sea water and a plant was built on the coast of North Carolina which now is extracting about 46,000 lb of bromine per day from 145 million gallons of sea water.

Displacement of Coal by Fuel Oil

Liquid fuel was tried on ships before the World War and by the close of the War virtually all the navies were burning oil. The merchant marine followed and the oil-fueled tonnage of the world rose from 18 per cent in 1920 to 40 per cent in 1930 and to 50 per cent in 1936.

* From the author's presidential address at the Fortieth Annual Meeting of the American Society for Testing Materials, New York, June 28 to July 2, 1937.

Forty per cent of the oil-fueled tonnage in 1936 consisted of diesel-powered ships. The railroads also have been and are today large consumers of fuel oil. While this has been limited largely to the Southwestern and Western States where coal is less available and fuel oil abundant, the later advent of diesel-motored trains is encroaching on the use of coal in other regions.

The most recent trend is the ever-accelerating gain of oil heating for homes and buildings. The sale of heating

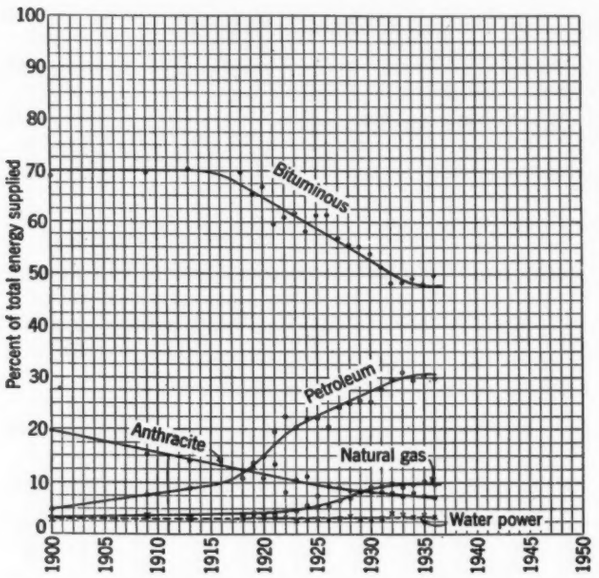


Fig. 1—Percentage of total energy supplied by mineral fuels and water power from 1900 to 1936

and range oils increased from 25 million barrels in 1926 to almost 100 million barrels in 1936. One hundred million barrels of oil is equivalent to 24 million tons or one-half of the present production of anthracite. In all its uses the consumption of fuel oil alone is equivalent to about 100 million tons of coal—slightly more than one-fifth of the total production of anthracite and bituminous coal combined.

Rise of Natural Gas

Next to petroleum the most striking development in our fuel supply is the utilization of natural gas. Although employed for lighting Fredonia, N. Y., as early as 1821, the use of natural gas was sporadic until the discovery of reservoirs of gas in the search for oil. The Munroe field of Louisiana, discovered in 1916, indicated a reserve of 5 trillion cubic feet of gas which was enough to justify long distance pipe lines to centers of consumption. These were built in 1926 to New Orleans, Memphis, St. Louis, Birmingham and Atlanta. The largest reserve of all proved to be the Amarillo, or Panhandle field in Texas, estimates of which vary up to 41 trillion cubic feet of gas. Pipe lines from this field have been extended to Fort Worth, Denver, Kansas City, Chicago, Minneapolis and Detroit.

Fifty-five per cent of the natural gas produced and consumed in the Unites States comes to the surface of the ground in association with oil. From 0.5 to 10.0 gal of gasoline and condensable hydrocarbons can be recovered from 1000 cubic feet of "wet" gas by compression and refrigeration or by absorption in oil.

Coal Production and Utilization

From 1898 to 1918 the production of bituminous coal increased at an average rate of approximately 20 million tons per annum, reaching a maximum of 570 million tons in 1918, which was the end of the rise. From that date the demand for coal wavered with the ups and downs of industry until in 1927 there began a decline which ended at a little over 300 million tons in 1932, and in 1936 production had returned to 434 million tons.

To hold the house-heating trade, coal producers are cooperating with appliance manufacturers in the development of automatic stokers which provide much of the convenience of gas- or oil-fired furnaces at a lower cost of fuel. The sales of domestic stokers have increased from 7000 in 1932 to 76,000 in 1936.

In the generation of power from coal the public utilities and the power plant equipment manufacturers have made great strides in improving fuel efficiency. From an average consumption of 7.05 lb of coal per kilowatt-hour in 1899 and 3.2 lb in 1919 to 1.44 lb in 1936, is a truly remarkable record. Since the most efficient modern stations are producing 1 kwhr from 0.8 lb of coal, further decrease of the average may be expected as new equipment replaces the old. However, the best boiler furnaces are nearing their maximum possible efficiences and further improvement of total fuel-power efficiency must be obtained in the conversion of steam

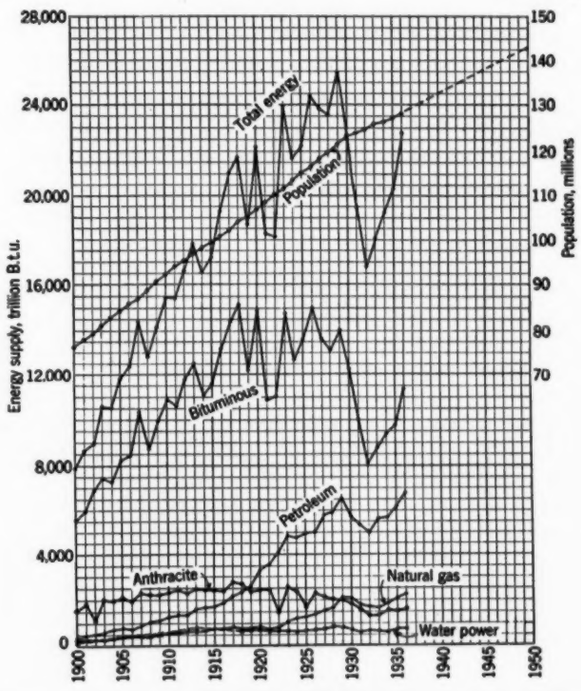


Fig. 2—Energy supply of the United States from 1900 to 1936 in trillion Btu, compared with increasing population

to power. Metallurgical progress in the development of high-temperature alloy steels permits the use of higher steam pressures. The best record for a coal-steam-turbine plant is 10,900 Btu per kwhr, or 31 per cent efficiency, which was obtained by the Port Washington Station (Milwaukee) operating at 1230 lb pressure and 825 F steam temperature. Mercury-vapor plants, still in the developmental stage, have given 32 per cent efficiency in regular operation.

Carbonization and Gasification of Coal

Fifteen years ago the prospects of the coal-carbonization industry seemed very bright. The public was learning to burn coke and to appreciate its smokeless properties. The demand for gas was increasing and the supply of natural gas from the Appalachian fields was declining; the demand for gasoline was mounting rapidly

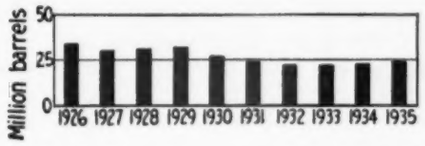


Fig. 3—Fuel oil used by gas and electric utilities

and discovery of new fields seemed inadequate. Further processing of coal for coke, gas and liquid by-products appeared inevitable; but unfortunately for the coal industry, the situation changed and a prolific period of discovery was followed by a veritable flood of oil and a hurricane of gas.

However, other factors also depressed the economics of coal carbonization. At present metallurgical coke is the only product from the processing of coal that does not have its price realization fixed by a competitive product. Light oil is controlled by gasoline; tar by fuel oil; ammonium sulphate by synthetic ammonia; and manufactured gas by natural gas. The commercial development of low-temperature carbonization, which provides an easily ignitable smokeless fuel, likewise has been retarded in the United States by the lack of demand for the light and heavy oils that are yielded in much greater volume than in the high-temperature process.

Present-Day Fuel Supply and Demand

We have solid, liquid and gaseous fuels in abundance, and are using them at an increasing rate. The total energy supply from these mineral fuels increased from 14,000 trillion Btu in 1907 to 24,600 trillion Btu in 1929—a 75 per cent increase in 22 years. The Depression caused a drop to 16,132 trillion Btu but recovery raised the figure to 21,800 trillion Btu by 1936. The changing proportions of this energy contributed by the several mineral fuels and by water power from 1900 to 1936 are shown in Fig. 1, and in Fig. 2 is given the proportion of energy supply, in trillion Btu, together with the increase in population for these years. The distribution of energy consumption in 1929, a year of high industrial activity, is given in Tables I and II. In round numbers, industry and public utility power consumed 45 per cent, transportation about a third and domestic and miscellaneous uses about one-fourth of our energy supply. Coal constituted 84 per cent of the fuel for domestic and miscellaneous purposes, 73 per cent for industrial use and public utility power and 57 per cent for transportation. Petroleum provided 43 per cent of transportation fuel, including practically 100 per cent of road vehicles and airplane fuel, 73 per cent of marine fuel and 11 per cent of railroad fuel. Natural gas comprised 16 per cent of industrial and public utility power consumption and 7 per cent of the domestic and miscellaneous needs. The consumption of fuel oil by utilities from 1926 through 1935 is indicated in Fig. 3.

During 1936 we produced and consumed 31 to 33 per cent of the world production of coal, 60 to 70 per cent of the petroleum and 95 per cent of the natural gas. We have a little over one-half (3.2 trillion tons of coal and lignite) of the world reserves of coal, and probably 60 per cent of the proved oil reserves. Two-thirds of the oil produced in all countries since its discovery in 1859 has come from American wells.

The deposits of oil shale, largely in the Rocky Mountain States, are estimated to contain a potential supply of 92 billion barrels of crude oil—an amount sufficient to maintain the present annual rate of oil production for nearly 100 years. The ultimate reserve of natural gas cannot be estimated.

The original reserves of coal and lignite are estimated at 3.2 trillion tons—enough to cover the entire state of Ohio to a depth of 76 ft. Not more than 2 per cent of the original supply of bituminous coal and about 25 per cent of the anthracite has been exhausted. At the 1929 rate of energy consumption, assuming that coal will carry the load after oil, gas and oil shale are exhausted, and allowing 30 per cent for loss, coal would last 2100 years. However, there certainly will be an increase in energy demand. An increase at the rate prevailing during the 'twenties would cut the foregoing period to some 500 years and a shortage of supply would be felt in the Appalachian field in the next 100 years. It must be remembered, however, that the superior coals of the Eastern region comprise only one-seventh of the

TABLE I

DISTRIBUTION OF ENERGY CONSUMPTION OF MINERAL FUELS IN 1929

	Coal, Million Net Tons			Petroleum, Million Barrels					Natural Gas	
	Anthracite	Bituminous		Gasoline		Kerosene,	Fuel and Gas Oil		Billion	
	Tons	Tons	Per Cent	Barrels	Per Cent	Barrels	Barrels	Per Cent	Cu Ft	Per Cent
Transportation	..	143	27.7	351	92.9	..	174	47	..	..
Railroads	..	135	26.2	1.1	0.3	..	76	20.5	..	..
Ships and boats	..	8	1.5	0.8	0.2	..	98	26.5	..	..
Road vehicles and airplanes	..	...	...	349.1	92.4	..	...	...	..	..
Public utility power	..	38	7.3	...	...	..	10	2.7	113	6
Public utility gas	..	6	1.3	...	...	..	22	6.0	..	..
Industrial	..	225	43.3	13.6	3.6	..	127	34.3	1444	75
Domestic and miscellaneous	69	106	20.4	13.2	3.5	36	37	10.0	360	19
Totals	69	518	100	378	100	36	370	100	1917	100

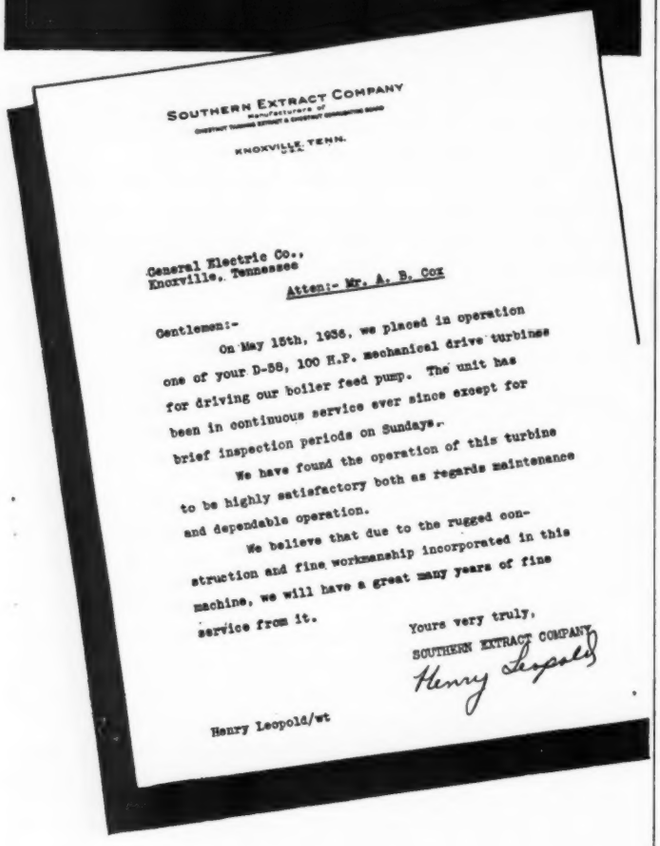
TABLE II

PERCENTAGE OF ENERGY SUPPLIED BY THE SEVERAL MINERAL FUELS FOR CERTAIN MAJOR USES IN 1929

Kind of Fuel	Domestic and Miscel.	Public-Utility Power, Gas and Industrial	Railroads	Ships	Road Vehicles and Airplanes	Total Trans.
Coal	84	73	89	27	...	57
Petroleum	9	11	11	73	100	43
Natural gas	7	16[a]	...	...	...	...
Totals	100	100	100	100	100	100

[a] Two-thirds of this 16 per cent used for gas and petroleum field operations, oil-refining fuel and production of carbon black.

G-E TURBINE "HIGHLY SATISFACTORY" Says Southern Extract Company



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Manufacturers of
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General Electric Co.,
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Atten:- Mr. A. B. Cox

Gentlemen:-

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We have found the operation of this turbine to be highly satisfactory both as regards maintenance and dependable operation.

We believe that due to the rugged construction and fine workmanship incorporated in this machine, we will have a great many years of fine service from it.

Yours very truly,
SOUTHERN EXTRACT COMPANY
Henry Leopold

Henry Leopold/wt

THIS turbine has served Southern Extract for a year—a year of almost continuous service, a year of highly satisfactory operation. Years of additional service can be confidently expected.

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GENERAL ELECTRIC

720-295

total reserves and one-half of the reserve consists of sub-bituminous coal and lignite, which are in the western part of the United States.

Fuels of Tomorrow

An appraisal of present trends and future probabilities indicates that:

1. Coal will continue to be the principal fuel used for the generation of public utility and major industrial power. Technologic improvements and new hydro-electric power will tend to reduce the consumption of coal. On the other hand, an increasing demand for energy and a decreasing supply of cheap residual oil will increase the amount of coal consumed for power purposes. No material change is expected in either direction in the near future, but in 10 or 15 years the trend will favor increased consumption of coal.
2. No substitute has appeared for metallurgical coke. The coke-oven industry will expand and consume more coal in accordance with metallurgical needs.
3. The convenience and uniformity of automatic heating of homes with gas or oil will continue to attract more users, even at higher costs than those prevailing today. Stoker-fired domestic furnaces, now in their beginning, eventually will give automatic service at a lower cost than for oil or gas, and high- and low-temperature cokes will supplement anthracite as solid smokeless fuel.
4. In 1929, 88 per cent of the railroad fuel was coal. Since then diesel locomotives have been adopted by several railroads for light-weight, high-speed passenger trains and an increase in diesels for such service is expected, but no general change in freight haulage from steam to diesel power is likely to take place.
5. Marine transportation is energized by oil. Approximately three-fourths of the marine fuel used in 1936 was oil, and 40 per cent of this oil was used in diesel engines. This trend will continue.
6. From the very beginning of the automobile industry recurring threats of shortage of gasoline were met by finding new pools and improving production technique, and in the refinery, by increasing yields and making a more efficient product. The end has not been reached. We are just beginning to use scientific methods in extracting oil from the sands and catalytic polymerization and hydrogenation eventually will furnish the means for complete conversion of volatile liquids and heavy petroleum to gasoline.

World Power Conference Meetings

Plans for future World Power Conference meetings were made at a session of the International Executive Council at Paris on June 29. It was decided to hold a sectional meeting in Vienna late in August of next year at which energy requirements of agriculture, electric railways, domestic and small industry use will be discussed. Tentative plans were also made for holding a second Chemical Engineering Congress in Berlin in 1940 and an invitation from the Japanese Government was accepted for holding the Fourth Plenary Meeting of the World Power Conference in Japan in 1942.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

High-Temperature Furnace Gases Used to Dry Wet Coal

In contrast to the Krämer mill firing system reviewed in the July 1937 issue of COMBUSTION, the Kohlenscheidungs Gesellschaft mill drying method of firing wet coals, as described in the July 1937 issue of *Archiv für Wärmewirtschaft und Dampfkesselwesen*, is of interest. The former method, it will be recalled, employs coarse grinding with the furnace serving as a separating chamber and a grate for burning the coarse fuel. In the latter method fine grinding is employed, thus eliminating the necessity for a grate, and the wet fuel is almost completely dried by intimate mixing before and during grinding with hot furnace gases at around 1750 F. The furnace volume is relatively small and the fine grinding is obtained with low power consumption.

Referring to Fig. 1, the wet coal is fed into the top of a long vertical chamber where it comes in contact with the hot furnace gases and at the bottom of which is located the mill. This also acts as a fan and sucks in the required quantity of hot gas and discharges through a classifier to the furnace at high velocity. The mill is motor-driven with an overhung water-cooled bearing.

In contrast with the Krämer system the furnace with the Kohlenscheidungs system is completely water-cooled and the volume for a given capacity would be about 72 per cent of the former. There is also closer control of the firing conditions. As to capacity, further comparison, based on the boilers at Böhlen, Hirschfelde and Zschornewitz, the present method will handle 5 to 6 tons per foot of furnace width whereas the Krämer furnace handles from 2.7 to 4 tons.

The Kohlenscheidungs method is designed for application only where the surface moisture of the fuel runs from 15 to 20 per cent or over.

Power in Japan

The Electrotechnical Journal, the new publication of the Institute of Electrical Engineers of Japan, contains an article on "Power Generation and Transmission in Japan" which gives the total 1936 central station production of electricity as slightly over 24 billion kilowatt-hours, 81.2 per cent of which was generated by water power and 18.8 per cent by steam.

The total number of hydro plants is 1340 with a combined rated capacity of 3,650,000 kw—an average of 2720 kw per plant. There are, however, seven stations of over 50,000 kw present installed capacity.

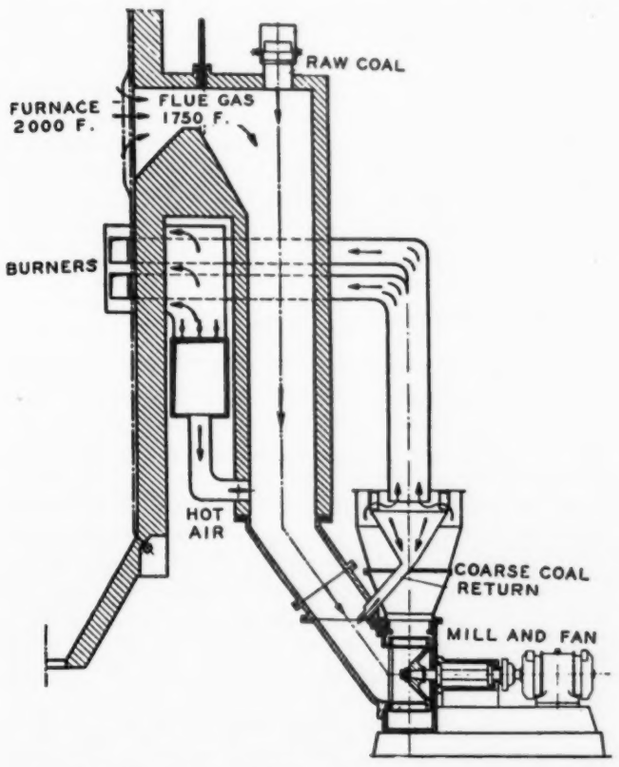

Fig. 1—Showing method of feeding and drying coal

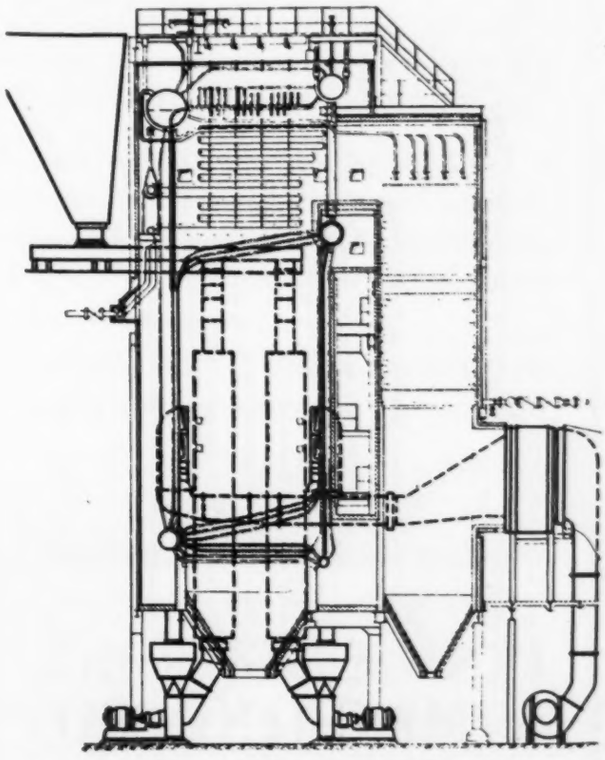

Fig. 2—Section through the steam-generating unit

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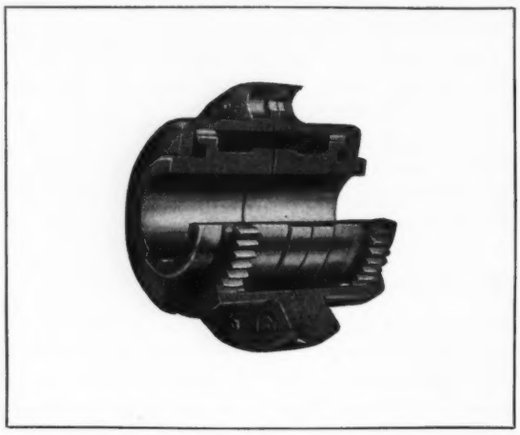

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At the end of 1936 there were 217 steam-electric central stations having a combined capacity rating of 2,140,000 kw. Of these, 49 were of more than 10,000 kw and furnished 89 per cent of the steam generated power. The largest of these now in operation is the Amagasaki Station of the Kansai Kyodokaryoku Hatsuden K. K., built in 1933 and extended in 1936, which has an installed capacity of 318,000 kw with twelve pulverized coal fired boilers and six 53,000-kw turbine-generators. It operates at 600 lb steam pressure and 833 F total steam temperature. The same company is building a second station, adjacent to this, which will contain six 75,000-kw machines. These will be the largest turbine-generators yet built in Japan.

Although the highest steam pressure now in use in Japan is 750 lb at the Ohura Station, the Sanyo Chuo Suiden K. K. is planning to top the Shikama No. 3 Station with a 10,000-kw unit that will take steam at 1900 lb and exhaust at 600 lb to two existing 35,000-kw units.

These steam stations are mostly located on the coast and the majority are interconnected with hydro systems.

As to industrial steam power plants, the article gives 235 of more than 1000 kw with a total rated capacity of 674,460 kw. Ten of these exceed 10,000 kw and one, the Nihon Iron Works, has 68,000 kw.

High-Pressure Reciprocating Engine

Die Wärme for June 5, 1937 describes a high-pressure reciprocating engine recently built by Schweizerische Lokomotiv und Maschinenfabrik of Winterthur, Switzerland, to operate at 1400 lb steam pressure, 750 F total steam temperature, and exhaust nominally at 28 lb to process. The unit is of uniflow design with three cylinders ($7^7/_8$-in. diameter by $13^3/_4$-in. stroke) and is rated at 1500 hp at 500 rpm. For operation at higher back pressures up to 140 lb, auxiliary exhaust ports are provided which open after the piston has started on the return stroke.

Steam is supplied by an Atmos boiler and the engine develops 910 kw compared with 550 kw for the turbine which it replaced. In this connection, the author observes that the reciprocating engine is more efficient than the turbine for small steam flows at high pressure under conditions that often obtain in industrial plants.

Hot Water Central Heating

The *Sulzer Technical Review*, No. 2, 1937, recently issued, contains a description of the municipal district heating system and power station at Lausanne, Switzerland. Here hot water at considerably over 212 F was chosen as the heat transmission medium in preference to steam chiefly because it eliminated the use of many traps and permitted a lower back pressure on the turbine. Although the power used in pumping the water may be an important factor where the cost of electric energy is high, this situation did not obtain in the present case. Furthermore, it is pointed out that the energy consumed in overcoming the friction in the mains is returned in the form of heat, so that there is little loss from this source.

The power plant, which also supplies electricity, contains two steam turbines and two diesel engines having a combined capacity of 7000 kw, and the existing boiler

plant has been extended by the addition of a Sulzer high-pressure boiler burning coke breeze from the municipal gas works. A high-pressure turbine is to be added later.

Surplus hydroelectric energy is utilized in an electric boiler connected directly into the heating system. Steam from the turbines goes to heat exchangers of the closed type which also serve the heating system. Heat storage is effected by two large water tanks located between the outgoing and the return lines, also by two similar high-temperature water tanks connected with the electric boiler which is used only when there is an excess of hydro power.

From the power house the high temperature water is carried through a double pipe line system to individual substations containing additional heat exchangers for the several services supplied.

Atmospheric Pollution in England

The twenty-second report by the British Government on "The Investigation of Atmospheric Pollution" for the year ended March 31, 1936 has just been published and is reviewed in the June 25 issue of *Engineering*. It is noted that there has been a definite reduction in the extent of atmospheric pollution during the past twenty years. On the other hand, there has been a slight increase during the past two years, a result which is ascribed to the increased industrial activity. The total solids deposited together with the sulphates and the tar estimated therefrom are taken as indications of pollution. On this basis, London from 1922 to 1936 showed little change in the total solids but this was accompanied by an increase in sulphates and tar. However, if the amounts of sunshine recorded in London are taken as a basis, the percentage of winter sunshine has increased from 20 to 52 since 1881. At Edinburgh the pollution is becoming worse.

In the case of suspended impurities there is general indication of improvement, although this is accompanied by much the same oscillations as those noted in the case of solids. As regards pollution from sulphur gases, which is mainly a winter problem, observation was made at eleven stations. London showed the highest average pollution and a very marked seasonal effect which goes to show that domestic fires are the principal source. The sulphur pollution at Greenwich seems to be about one-third of that in the vicinity of Westminster, which suggests that in central London there are sources of sulphur pollution which are not serious sources of smoke pollution. This points to the industrial furnaces which have no provision for the absorption of sulphur as being one of the causes of the sulphur pollution in London.

Schmidt-Hartmann Boiler for Marine Service

According to a description in *Engineering and Boiler House Review* for July, a high-pressure Schmidt-Hartmann boiler is now nearing completion for a freighter of the Argo Line, Bremen, Germany. In this type of boiler, it will be recalled, the evaporation of the working steam does not take place in the boiler surface proper, but instead in an evaporator drum heated by coils supplied from a primary steam circuit operating at a higher pressure than that of the working steam. The heat absorbing part of the primary circuit takes the place of the ordinary boiler

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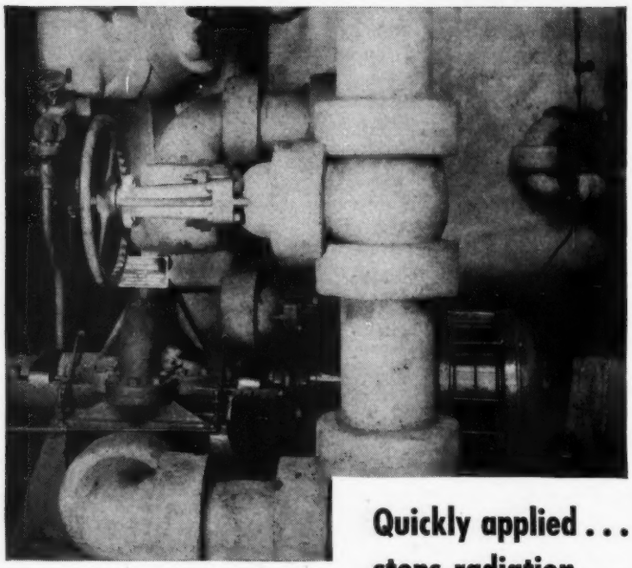

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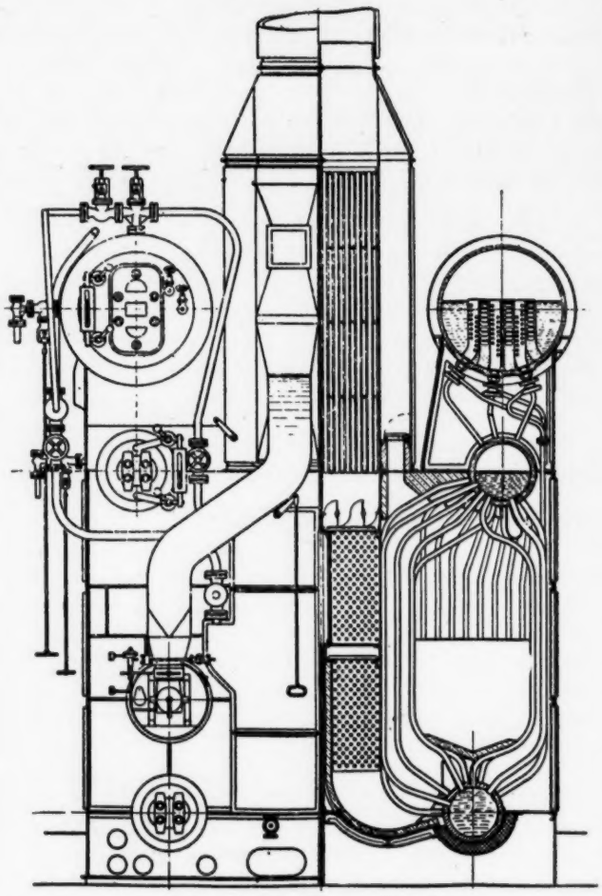

Schmidt-Hartmann Boiler

surface and consists of both radiant and convection surfaces as shown in the illustration.

The evaporator elements in the drums are made up of groups of inclined straight tubes.

To safeguard the superheater against overheating in starting up, a gas bypass is provided and superheat regulation is obtained by means of dampers. In addition, an automatically operated desuperheater is provided.

In this installation the working steam at 738 lb per sq in. and 887 to 932 F will supply the high-pressure cylinder of a quadruple-expansion engine of the Lentz type.

British Discuss Dual Firing

The Fuel Economist (London) for July comments editorially upon the controversy that is now going on concerning the proposal to equip British naval vessels to burn either coal or oil. On the one hand, it is argued that England, with abundant supplies of coal, is dependent upon the importation of fuel oil, the supply of which might be cut off or seriously curtailed in time of war. Therefore, if the ships were equipped for dual firing this menace would be removed. Opposed is the contention of many naval officers that oil-fired ships cost less, can be refuelled in less time, are faster and require a smaller personnel, but that the government should give greater attention to producing oil from coal.

Spokesmen for the government admit that the question of oil supply has been giving some concern but that technical arguments are so strongly in favor of oil as to outweigh the problem of obtaining it from overseas.